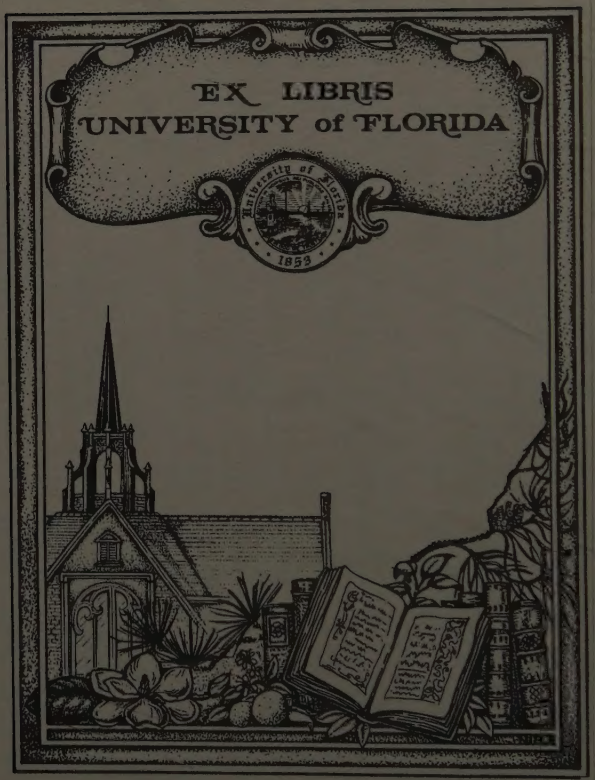

EX LIBRIS
UNIVERSITY of FLORIDA
University of Florida
1853

MANUAL OF ENTOMOLOGY

WITH SPECIAL REFERENCE TO ECONOMIC ENTOMOLOGY

Withdrawn from UF. Surveyed to Internet Archive

BY

H. MAXWELL-LEFROY, M.A.

PROFESSOR OF ENTOMOLOGY,
IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

UNIVERSITY OF FLORIDA
LIBRARY

ILLUSTRATED BY L. N. STANILAND

LONDON
EDWARD ARNOLD & CO.
1923

[*All rights reserved*]

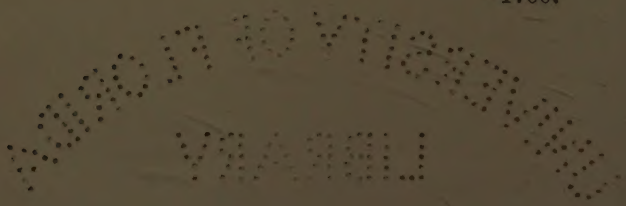
529

595.7
M 465m

595.7
M465m

Ce n'est pas seulement dans les animaux d'une grosseur remarquable, que la Providence divine est merveilleuse. Elle éclatte aussi, dans les plus petits, comme on le voit dans les Insectes.

JEAN GOEDAERT.
1700.



Made and Printed in Great Britain by
Butler & Tanner, *Frome and London*

PREFACE

This volume is based upon the lectures given as the second f three parts of a course occupying one year of a full training n economic entomology. To compile in book form a complete ntomology, apart from description of species, would occupy nany years and fill many volumes. In lecturing one's attempt s to pick out what the student can know—essentials, and not etails, are the requisite—and this volume attempts to select he usual ordinary facts about each group, which the student equires. The unusual, the "romantic," is cut out; there is o romance of nature, but the solid sober facts of the habits nd life-histories, so far as we know them, of the usual insects. While admiring the "romance" of the insect that really does xtraordinary things, it is not the basis required by the student f economic entomology, who will presently be dealing with n outbreak of a pest that affects the welfare or lives of many eople.

I have tried to adhere to a sequence of subject-ideas: name, opular name, diagnosis, geographical distribution, appearance nd recognition in the field, external structure, sex recognition, ternal structure, life history, habitat, food, literature, uthorities, economic importance. For the student of econo- ic entomology, some of these headings are important; he ants to know how to recognize his live insect in the field; wants to be able to recognize sex; if he catches any insect, has one sent in to him, he wants to be able immediately to now what are its likely habits; he wants a reference to a

140570

catalogue or monograph giving him all the literature to a date. So I have dealt lightly with structure and morphology, more fully with habits and checks, and given a reference to the latest catalogue or monograph.

I assume every student or worker can use the *Zoological Record*, *Genera Insectorum*, and the *Review of Applied Entomology*. In view of this, references are given as "Smith 1920" and so on; anyone can look these up.

Two points are of importance: firstly, no student of economic entomology can devote much time to absolute morphological accuracy—it matters more to him how mouth-parts function than what is the correct name of each part; and secondly, the last word in nomenclature is really unimportant. Of course, if one species attacking a variety of food plants can be readily proved to be several distinct ones, that is genuine non-interbreeding species, that is of great importance. If you have a supposedly single species that feeds on maize, cane and rice, and which is really a different species feeding on each type of plant, it is of no use as a remedy to use maize as a trap plant for the cane species. But, in our times, the limit of species has been enormously overdone: the fact that vein 7 comes off from vein 6 before, at, or beyond the junction of vein 5, is a hopeless criterion if, on it, you are to base large economic measures. So we have to tone down, as far as we can, in economic practice, the minute criteria of the systematist.

Lastly, I cannot hope to deal with the changes in nomenclature and do not attempt to; our old friend *Heliothis armigera* is to some *Chloridea obsoleta*, all the old references are under the former name, and they contain much good work. The curse of our subject is this continual changing of nomenclature on grounds of priority. Some day entomologists will realize how they handicap their science; may this day come soon. I have had to take a middle course,

one between that of the ultra-conservative and the ultra-nomenclaturist.

For students it has been necessary hitherto to rely on Sharp's volumes on Insects in the *Cambridge Natural History*, but these are now out of date, and while very admirable in parts (e.g. *Orthoptera*) are not really adequate in many groups (e.g. *Curculionidæ*). For training in economic entomology tropical groups are so important that *Indian Insect Life* has been in constant use in this College, but is now no longer obtainable.

The underlying idea of this book is best expressed as follows: Imagine seven entomologists in Piccadilly Circus, and that they see a beetle crossing the road. The systematist says, "*Carabus octodecimpunctata* Smith var. *Nigro-fasciata* Jones," and his interest ends there. The morphologist says, "Beetle, with undeveloped hypopharynx, dieroistic egg-tubes, etc., etc.," and his interest ends. The collector says, "Ordinary common variety, ten males and females in my collection," and passes on. The Mendelist speculates, thinks back over literature of inheritance in *Carabidæ*, and wishes he were back in his library. The evolutionist speculates also, as to the common ancestor of *Carabidæ* and *Dermaptera*, as to whether the carabœoid or scarabæoid larva came first, and also passes on speculating. The bionomist says, "Carabid, carnivorous, free living, no business to be here," and the economic man says much the same, but wonders what he would do if an outbreak of these occurred in Piccadilly and he was called on to cope with it. It is the last two men that I attempt to interest.

Illustrations are reduced to the barest minimum, as I do not believe in encouraging identification from pictures. Every student should work with a collection, and, when reading up a group, have actual specimens to examine and dissect. Some illustrations are from *Indian Insect Life*, and therefore not acknowledged, as they are my copyright.

In the preparation of a large part of the text I owe acknowledgment to the following past and present students of this department of the College:—

Mr. A. S. Buckhurst, for *Embioptera* and *Lepidoptera*;
Mr. L. C. Bushby, ,, *Coleoptera*, *Strepsiptera*, *Anoplura* and part of *Rhynchota*;
Mr. B. A. R. Gater, ,, *Orthoptera*, *Isoptera*, *Psocoptera* and *Dermaptera*;
Mr. C. B. R. King, ,, *Diptera* and *Siphonaptera*;
Mr. S. S. Light, ,, *Protura*, *Thysanura*, *Collembola*, *Zoraptera*, and *Thysanoptera*;
Mr. L. N. Staniland, ,, *Aphidæ* and *Psyllidæ*:
Mr. E. B. Watson, ,, *Mallophaga* and *Hymenoptera*;
Mr. C. L. Withycombe ,, *Plecoptera*, *Ephemeroptera*, *Odonata*, *Megaloptera*, *Neuroptera*, *Trichoptera*, and *Mecoptera*.

I have also to acknowledge the assistance of Mr. D. S. Wilkinson in reading through and preparing for the press some part of the manuscript.

H. M. LEFROY.

HESTON, 1923.

CONTENTS

SCHEME OF CLASSIFICATION

Families printed in heavy type are those which are important to the student of economic entomology.

INSECTA:

APTERA

1. PROTURA (*Myrientomata-Anamerentoma*)

Acerentomidæ . . Page 5 | Eosentomidæ . . Page 5

2. THYSANURA

Campodeidæ . . Page 8 | Machilidæ . . . . ,, 11
Projapygidæ . . ,, 9 | Lepismidæ . . . . ,, 12
Japygidæ . . . ,, 10 |

3. COLLEMBOLA

Arthropleona

Achorutidæ . . . Page 17 | Entomobryidæ . . ,, 18

Symphypleona

Sminthuridæ. . . ,, 19 | Neelidæ (Megalothoracidæ) ,, 20

PTERYGOTA

4. PLECOPTERA (*Perlaria. Platyptera*)

(*Perlidæ*) . . . . . ,, 21

5. EPHEMEROPTERA (*Ephemerida. Plectoptera. Agnatha*)

(*Ephemeridæ*) . . . . . ,, 24

6. ODONATA (*Paraneuroptera*)

Anisoptera

Æschnidæ . . . Page 31 | Libellulidæ . . . . ,, 31

Anisozygoptera

Epiophlebiidæ . . . . . ,, 31

Zygoptera

Calopterygidæ . . Page 32 | Agrionidæ . . . ,, 32
Lestidæ . . . ,, 32 |

7. EMBIOPTERA

Embiidæ . . . . . ,, 33

8. ORTHOPTERA

Blattidæ . . . Page 39 | **Locustidæ** (Phasgonuridæ. Tettigonidæ) . . ,, 66
Mantidæ . . . ,, 45 |
Phasmidæ . . . ,, 51 | Grylloblattidæ . . ,, 72
Acridiidæ (Locustidæ) . ,, 54 | **Gryllidæ** (Achetidæ) . ,, 72

9. ISOPTERA

Termitidæ . . . . . Page 81

10. ZORAPTERA

Zorotypidæ . . . . . ,, 92

11. PSOCOPTERA

Psocidæ . . . . . ,, 95

12. MALLOPHAGA (*Lipoptera*)

Ischnocera

Trichodectidæ . . Page 102 | Philopteridæ. . . . ,, 102

Amblycera

Liotheidæ . . . Page 102 | Gyropidæ . . . ,, 102

13. DERMAPTERA (*Euplexoptera*)

Forficulidæ . . Page 103 | Hemimeridæ. . . . ,, 109
Arixeniidæ . . . ,, 108 |

14. COLEOPTERA

I. ADEPHAGA

Cicindelidæ . . . Page 119 | Dytiscidæ . . . ,, 123
Carabidæ . . . ,, 120 | Gyrinidæ . . . ,, 124
Amphizoidæ . . . ,, 121 | Paussidæ . . . ,, 125
Pelobiidæ (Hygrobiidæ) . ,, 122 | Rhysodidæ . . . ,, 126
Haliplidæ . . . ,, 122 | Cupedidæ . . . ,, 126

II. POLYCERATA

(*a*) *Staphylinoidea*

Staphylinidæ . . Page 127 | Sphæridæ . . . ,, 133
Pselaphidæ . . . ,, 129 | Corylophidæ . . . ,, 133
Gnostidæ . . . ,, 129 | Phænocephalidæ . . ,, 134
Scydmænidæ. . . . ,, 130 | Pseudocorylophidæ . ,, 134
Silphidæ . . . ,, 130 | Scaphidiidæ . . . ,, 135
Clambidæ . . . ,, 131 | Histeridæ . . . ,, 135
Leptinidæ . . . ,, 132 | Niponiidæ . . . ,, 136
Trichopterygidæ . . ,, 132 | Platypsyllidæ . . ,, 137
Hydroscaphidæ . . ,, 133 |

(*b*) *Clavicornia*

Synteliidæ . . . Page 137 | Lathridiidæ . . . ,, 146
Sphæritidæ . . . ,, 138 | Mycetophagidæ . . ,, 147
Trogositidæ (Temnochilidæ. Colydiidæ . . . ,, 148
Ostomidæ) . . ,, 138 | Adimeridæ . . . ,, 149
Helotidæ . . . ,, 139 | Endomychidæ . . ,, 149
Byturidæ . . . ,, 139 | **Coccinellidæ** . . ,, 150
Nitidulidæ . . . ,, 140 | **Dermestidæ**. . . ,, 152
Cucujidæ . . . ,, 141 | Byrrhidæ . . . ,, 153
Monotomidæ. . . . ,, 142 | Nosodendridæ . . ,, 154
Erotylidæ . . . ,, 143 | Cyathoceridæ . . ,, 155
Crytophagidæ . . ,, 144 | Georyssidæ . . . ,, 155
Catoprochotidæ . . ,, 144 | Dryopidæ (Parnidæ, including
Phalacridæ . . . ,, 145 | Elmidæ) . . . ,, 156
Thoractidæ . . . ,, 145 | Hydrophilidæ . . ,, 157
Derodontidæ . . . ,, 146 | Heteroceridæ. . . ,, 158

(c) *Serricornia*

Dascillidæ (Psephenidæ. Cyphonidæ) . . Page 159
Helodidæ . . . „ 160
Rhipiceridæ . . . „ 161
Cantharidæ (Telephoridæ. Malacodermidæ). . . „ 162
Melyridæ . . . „ 164
Cleridæ. . . . „ 165
Lymexylonidæ . . „ 166
Anobiidæ (Ptinidæ) . Page 167
Bostrychidæ . . „ 168
Lyctidæ . . . „ 169
Sphindidæ . . . „ 170
Cioidæ . . . . „ 171
Buprestidæ . . „ 171
Elateridæ . . . „ 173
Throscidæ (Trixagidæ) . „ 175

(d) *Heteromera*

Tenebrionidæ . . Page 176
Ægialitidæ . . . „ 178
Lagriidæ . . . „ 178
Othniidæ . . . „ 179
Cistelidæ (Alleculidæ) . „ 180
Monommidæ . . . „ 180
Nilionidæ . . . „ 181
Petriidæ . . . „ 181
Œdemeridæ . . . „ 182
Pythidæ . . . „ 183
Melandryidæ. . . „ 184
Scraptiidæ . . . „ 185
Mordellidæ . . . „ 185
Rhipiphodiræ . . „ 186
Meloïdæ (including Lyttidæ) „ 188
Pyrochroidæ . . . „ 189
Xylophilidæ . . . „ 190
Anthicidæ (Hylophilidæ. Pedilidæ) . . . „ 191
Trictenotomidæ . . „ 192

(e) *Phytophaga*

Lariidæ (Bruchidæ) . Page 193
Chrysomelidæ . . „ 194
Cerambycidæ . . „ 197
Lamiidæ . . . „ 200

(f) *Rhynchophora*

Brenthidæ . . . Page 201
Platyrrhinidæ (Anthribidæ) „ 202
Curculionidæ . . „ 203
Scolytidæ (Ipidæ. Platypidæ) „ 206
Aglycyderidæ . . „ 208
Proterhinidæ . . „ 209

III. LAMELLICORNIA

Passalidæ . . . Page 209
Lucanidæ . . . „ 211
Sinodendridæ . . „ 212
Scarabæidæ . . „ 213

15. STREPSIPTERA

Stylopidæ . . . . . „ 216

16. THYSANOPTERA (Physapoda)

I. POLYSTIGMATA

Urothripidæ . . . . . „ 225

II. TUBULIFERA

Phlœothripidæ . . . . . „ 225

III. TEREBRANTIA

Thripidæ . . . Page 225
Æolothripidæ . . „ 225

17. ANOPLURA

Hæmatomyzidæ . . Page 229
Pediculidæ . . . „ 230
Hæmatopinidæ . . „ 230
Echinophthiridæ . . „ 230

18. RHYNCHOTA (Hemiptera)

I. HETEROPTERA

(a) *Gymnocerata*

Pentatomidæ . . Page 237
Coreidæ . . . „ 238
Berytidæ . . . „ 239
Lygæidæ (Myodochidæ. Colobathristidæ) . „ 240
Pyrrhocoridæ . . „ 241

Tingidæ	Page 242	Saldidæ	Page 247
Aradidæ	,, 242	Aëpophilidæ	,, 248
Hebridæ	,, 243	Ceratocombidæ	,, 248
Hydrometridæ	,, 243	**Cimicidæ**	,, 249
Henicocephalidæ	,, 245	Anthocoridæ	,, 250
Phymatidæ	,, 245	Polyctenidæ	,, 250
Reduviidæ	,, 246	**Capsidæ** (Miridæ)	,, 251

(*b*) *Cryptocerata*

Pelogonidæ (Galgulidæ)	Page 252	Belostomidæ	,, 254
Nepidæ	,, 253	Notonectidæ	,, 255
Naucoridæ	,, 254	Corixidæ	,, 256

H. HOMOPTERA

Cicadidæ	Page 257	**Psyllidæ** (Chermidæ)	,, 264
Fulgoridæ	,, 259	**Aphidæ**	,, 268
Membracidæ	,, 260	**Aleurodidæ**	,, 276
Cercopidæ	,, 261	**Coccidæ**	,, 279
Jassidæ	,, 263		

19. MEGALOPTERIA

Sialidæ	Page 290	Raphidiidæ	,, 292

20. NEUROPTERA

Ithonidæ	Page 295	Berothidæ (including Trichomatidæ)	,, 303
Hemerobiidæ	,, 296	Chrysopidæ	,, 304
Dilaridæ	,, 298	Apochrysidæ	,, 306
Sisyridæ	,, 298	Mantispidæ	,, 306
Coniopterygidæ	,, 299	Nymphidæ	,, 308
Psychopsidæ	,, 301	Nemopteridæ	,, 309
Polystœchotidæ	,, 302	Myrmeleonidæ	,, 310
Osmylidæ	,, 303	Ascalaphidæ	,, 312

21. TRICHOPTERA

I. INÆQUIPALPIA

Phryganæidæ	Page 314	Sericostomatidæ	,, 314
Limnophilidæ	,, 314		

II. ÆQUIPALPIA

Calamoceratidæ	Page 314	Psychomyiidæ	,, 314
Odontoceridæ	,, 314	Polycentropidæ	,, 314
Leptoceridæ	,, 314	Philopotamidæ	,, 314
Molannidæ	,, 314	Rhyacophilidæ	,, 314
Hydropsychidæ	,, 314	Hydroptilidæ	,, 314

22. MECOPTERA

Bittacidæ	Page 318	Notiothaumidæ	,, 318
Boreidæ	,, 318	Meropidæ	,, 318
Panorpidæ	,, 318		

23. LEPIDOPTERA

I. RHOPALOCERA

Papilionidæ	Page 339	Erycinidæ (Lemoniidæ, Nemeobiidæ, Riodinidæ)	,, 345
Pieridæ	,, 340	**Hesperiidæ**	,, 346
Nymphalidæ	,, 341		
Lycænidæ	,, 344		

II. HETEROCERA

Syntomidæ (Amatidæ) . Page 348
Arctiidæ (Lithosiidæ) . ,, 348
Agaristidæ . . . ,, 350
Noctuidæ . . . ,, 350
Pterothysanidæ . . ,, 354
Lymantriidæ) Liparidæ) . ,, 354
Hypsidæ (Aganaidæ) . ,, 356
Sphingidæ . . . ,, 357
Cymatophoridæ (Thyatiridæ. Polyplocidæ) . . ,, 359
Eupterotidæ . . . ,, 359
Notodontidæ. . . ,, 360
Geometridæ . . ,, 362
Saturniidæ . . ,, 364
Bombycidæ. . ,, 366
Brahmæidæ . . ,, 367
Ceratocampidæ . . ,, 367
Uraniidæ (including Epicopeiidæ and Epiblemidæ) . Page 368
Psychidæ . . . ,, 369
Heterogynidæ . . ,, 370
Arbelidæ . . . ,, 370
Argyrotypidæ . . ,, 371
Ratardidæ . . . ,, 372

Cossidæ . . . Page 372
Lasiocampidæ . . ,, 373
Endromidæ . . . ,, 374
Chrysopolomidæ . . ,, 375
Perophoridæ . . . ,, 375
Megalopygidæ (Lagoidæ) . ,, 376
Limacodidæ (Eucleidæ. Heterogeneidæ. Cochlididæ) ,, 376
Dalceridæ . . . ,, 377
Neocastniidæ . . ,, 378
Castniidæ . . . ,, 378
Euschemonidæ . . ,, 379
Zygænidæ . . . ,, 379
Callidulidæ . . . ,, 380
Drepanidæ (Drepanulidæ) ,, 381
Thyrididæ . . . ,, 382
Pyralidæ . . . ,, 382
Orneodidæ (Alucitidæ) . ,, 387
Pterophoridæ . . ,, 387
Sesiidæ (Ægeriidæ) . ,, 388
Tortricidæ . . . ,, 389
Tineidæ . . . ,, 391
Hepialidæ . . . ,, 395
Micropterygidæ . . ,, 396

24. DIPTERA

I. ORTHORRHAPHA

(*a*) *Nemocera*

Tipulidæ . . . Page 415
Psychodidæ . . ,, 416
Dixidæ . . . ,, 418
Culicidæ . . . ,, 418
Chironomidæ. . . ,, 421
Cecidomyiidæ . . ,, 423
Mycetophilidæ . . ,, 425

Bibionidæ . . . ,, 426
Simuliidæ . . . ,, 427
Blepharoceridæ . . ,, 428
Deuterophlebiidæ . . ,, 429
Orphnephilidæ . . ,, 430
Rhyphidæ . . . ,, 430

(*b*) *Brachycera*

Leptidæ . . . Page 430
Stratiomyidæ . . ,, 431
Tabanidæ . . . ,, 431
Acanthomeridæ . . ,, 433
Pyrtidæ . . . ,, 433
Nemestrinidæ . . ,, 433
Apioceridæ . . . ,, 434
Mydaidæ . . . ,, 434

Asilidæ . . . ,, 434
Therevidæ . . . ,, 435
Scenopinidæ . . . ,, 435
Bombyliidæ . . . ,, 436
Empidæ . . . ,, 436
Dolichopodidæ . . ,, 437
Phoridæ . . . ,, 437
Lonchopteridæ . . ,, 438

II. CYCLORRHAPHA

(*a*) *Aschiza*

Platypezidæ . . . Page 438
Pipunculidæ . . ,, 438

Syrphidæ . . . ,, 439

(*b*) *Schizophora*

(*i*) Acalyptratæ

Conopidæ . . . Page 440
Micropezidæ . . ,, 441
Tanypezidæ . . ,, 441
Psilidæ . . . ,, 441
Ortalidæ . . . ,, 442

Trypetidæ . . ,, 443
Rhopalomeridæ . . ,, 445
Sapromyzidæ . . ,, 446
Agromyzidæ . . ,, 446
Oscinidæ . . . ,, 446

Drosophilidæ . . Page 448
Sepsidæ . . . „ 448
Ephydridæ . . . „ 449
Phycodromidæ . . „ 449
Heteroneuridæ . . „ 449
Sciomyzidæ . . . „ 450
Helomyzidæ . . . Page 450
Celyphidæ . . . „ 450
Borboridæ . . . „ 450
Diopsidæ . . . „ 451
Cordyluridæ . . . „ 451

(*ii*) Calyptratæ

Anthomyiidæ . . Page 452
Muscidæ . . . „ 453
Sarcophagidæ . . „ 457
Tachinidæ . . . „ 458
Dixiidæ . . . „ 460
Œstridæ . . . „ 461

(*c*) *Pupipara*

Hippoboscidæ . . Page 462
Nycteribiidæ . . „ 463
Streblidæ . . . „ 463
Braulidæ . . . „ 464

25. SIPHONAPTERA

Sarcopsyllidæ . . Page 468
Pulicidæ . . . „ 468
Ceratopsyllidæ . . . „ 470

26. HYMENOPTERA

I. Tenthredinoidea

Cephidæ . . . Page 480
Siricidæ . . . „ 482
Oryssidæ . . . „ 483
Tenthredinidæ . . „ 483

II. Cynipoidea

Cynipidæ . . . . . „ 486

III. Serphoidea

Proctotrypidæ . . Page 489
Platygastridæ . . „ 490
Scelionidæ . . . „ 490
Ceraphronidæ . . „ 490
Heloridæ . . . „ 490
Diapriidæ . . . „ 490
Belytidæ . . . „ 490
Serphidæ . . . „ 490
Pelecinidæ . . . „ 490

IV. Chalcidoidea

Mymaridæ . . . Page 491
Trichogrammidæ . . „ 491
Tetrastichidæ . . „ 491
Entedontidæ . . „ 491
Eulophidæ . . . „ 491
Elasmidæ . . . „ 491
Elachertidæ . . . „ 491
Pteromalidæ . . „ 491
Spalangidæ . . . „ 491
Tridymidæ . . . „ 491
Aphelinidæ . . . „ 491
Encyrtidæ . . . „ 491
Signiphoridæ . . . „ 491
Eupelmidæ . . . „ 491
Callimomidæ . . . „ 491
Eurytomidæ . . . „ 491
Perilampidæ . . . „ 491
Eucharidæ . . . „ 491
Chalcididæ . . . „ 491
Leucospidæ . . . „ 491

V. Ichneumonoidea

Ichneumonidæ . . Page 494
(Incl. Banchidæ)
Braconidæ . . . „ 496
(Incl. Vipionidæ. Alysiidæ. Capitonidæ)
Evaniidæ . . . „ 498
Stephanidæ . . . „ 499
Trigonalidæ . . . „ 499

VI. Chrysidoidea

Chrysidæ (Chrysididæ) . . . . . „ 500

VII. Vespoidea

Bethylidæ . . . Page 502
Dryinidæ . . . „ 503
Scoliidæ . . . „ 504
Sapygidæ . . . „ 505
Mutillidæ (Incl. Methocidæ. Myrmosidæ) . . „ 505
Thynnidæ . . . „ 507
Pompilidæ (Psammocharidæ) „ 507
Eumenidæ . . . „ 509
Vespidæ . . . „ 510
Masaridæ . . . „ 513

VIII. SPHECOIDEA

Ampulicidæ	Page 513	Mellinidæ	Page 514
Nyssonidæ	„ 513	Sphecidæ	„ 514
Psenidæ	„ 513	Larridæ	„ 514
Oxybelidæ	„ 514	Astatidæ	„ 514
Crabronidæ	„ 514	Pemphredonidæ	„ 514
Philanthidæ	„ 514	Bembicidæ	„ 514
Trypoxylonidæ	„ 514	Cerceridæ	„ 514

IX. APOIDEA (*Anthophila*)

Halictidæ	Page 516	Anthophoridæ	„ 516
Andrenidæ	„ 516	Hylœidæ	„ 516
Dufoureidæ	„ 516	Colletidæ	„ 516
Nomiidæ	„ 516	Stelididæ	„ 516
Macropidæ	„ 516	Megachilidæ	„ 516
Panurgidæ	„ 516	Ceratinidæ	„ 516
Nomadidæ	„ 516	Xylocopidæ	„ 516
Euceridæ	„ 516	Apidæ	„ 516
Emphoridæ	„ 516		

X. FORMICOIDEA

Formicidæ . . . . . „ 523

TABLE OF ORDERS adopted in this volume with corresponding orders in the *Cambridge Natural History* and in Sedgwick's *Textbook of Zoology*.

	Cambridge Natural History.	Sedgwick's *Textbook of Zoology.*
1. PROTURA	—	—
2. THYSANURA	*Aptera* (Thysanura)	*Apterygota* (Thysanura)
3. COLLEMBOLA	*Aptera* (Collembola)	*Apterygota* (Collembola)
4. PLECOPTERA	*Neuroptera* (Neur. Amphibiotica Perlidæ)	*Plecoptera*
5. EPHEMEROPTERA	*Neuroptera* (Neur. Amphibiotica Ephemeridæ)	*Ephemeroptera*
6. ODONATA	*Neuroptera* (Neur. Amphibiotica Odonata)	*Paraneuroptera* (Odonata)
7. EMBIOPTERA	*Neuroptera* (Pseudoneuroptera Embiidæ)	*Embioptera* (Corrodentia—part)
8. ORTHOPTERA	*Orthoptera*	*Orthoptera*
9. ISOPTERA	*Neuroptera* (Pseudoneuroptera-Termitidæ)	*Isoptera* (Corrodentia—part)
10. ZORAPTERA	—	—
11. PSOCOPTERA	*Neuroptera* (Pseudoneuroptera-Psocidæ)	*Psocoptera* (Corrodentia—part)
12. MALLOPHAGA	*Neuroptera* (Mallophaga)	*Anapterygota* (Mallophaga)
13. DERMAPTERA	*Orthoptera* (Forficulidæ)	*Orthoptera* (Forficulidæ)
14. COLEOPTERA	*Coleoptera*	*Coleoptera*
15. STREPSIPTERA	*Coleoptera* (Strepsiptera)	*Strepsiptera*

	Cambridge Natural History.	Sedgwick's *Textbook of Zoology.*
16. THYSANOPTERA	*Thysanoptera*	*Thysanoptera*
17. ANOPLURA	*Hemiptera* (Anoplura)	*Anapterygota* (Anoplura)
18. RHYNCHOTA	*Hemiptera* (part)	*Hemiptera*
19. MEGALOPTERA	*Neuroptera* (Neuroptera-Planipennia Sialidæ)	*Neuroptera* Sialidæ and Raphidiidæ)
20. NEUROPTERA	*Neuroptera* (Neuroptera-Planipennia)	*Neuroptera* (part)
21. TRICHOPTERA	*Neuroptera* (Trichoptera)	*Trichoptera*
22. MECOPTERA	*Neuroptera* (Neuroptera-Planipennia Panorpidæ)	*Mecaptera* (Panorpidæ)
23. LEPIDOPTERA	*Lepidoptera*	*Lepidoptera*
24. DIPTERA	*Diptera*	*Diptera*
25. SIPHONAPTERA	*Aphaniptera*	*Anapterygota* (Siphonaptera)
26. HYMENOPTERA	*Hymenoptera*	*Hymenoptera*

LIST OF PLATES

Plate		To face page
I.	Odonata, Ephemeroptera and Plecoptera	20
II.	Mecoptera, Megaloptera, and Ithone	288
III.	Neuroptera	295
IV.	Neuroptera	310

MANUAL OF ENTOMOLOGY

APTERA

Wingless insects derived from wingless ancestors. No metamorphosis. Primitive biting mouth-parts with maxillulæ.

The members of this group are extremely widely distributed, some genera being found all over the world; the *Thysanura*, however, are mainly tropical, and the *Collembola* mainly temperate.

The *Aptera* are possibly the most primitive of all insects, being allied, in many respects, to the *Myriapoda* and *Pauropoda*, more especially with regard to the head, legs, and abdominal appendages; even their embryology resembles that of *Myriapoda*. These very characters are those in which they differ most from the more advanced types of Insects. Some of the lines of development followed by the *Aptera* are actually more suggestive of the *Crustacea* than of the *Myriapoda*. Thus their common ancestor was, in all probability, a form intermediate between *Crustacea* and *Myriapoda*. The various classes of the *Aptera* are linked very closely together and their affinity to the *Pterygota* is so questionable that the suggestion of some authors that the former should be altogether removed from the *Insecta* is quite reasonable. They are all small, wingless, soft-bodied insects, in colour generally white or brown, black or grey, though some are quite brightly coloured; as a consequence of their living chiefly in concealment, the colour is of little significance.

The head is usually large and bears (except in *Protura*) a pair of well-developed antennæ with a varying number of joints. The mouth-parts consist of a labrum, a pair of mandibles, maxillæ with palps, a hypopharynx and a labium bearing labial palps; in many forms a pair of maxillulæ is also present (*Anurida*). In many cases, the mouth-parts are

retracted within the cavity of the head. Eyes may be present or absent.

There are three pairs of running legs clothed in hairs; one or two claws occur on the tarsi. The abdomen, which may be linear or globular in form, consists of from six to twelve segments. Abdominal appendages of varying form are always present, of which the most characteristic are the abdominal styles and sacs on segments one to eight, varying in the groups, and the long cerci of the *Thysanura* and the furcula and ventral tube of the *Collembola*. In all these insects, the body is clothed in hairs to a greater or less extent; sometimes longer clubbed hairs are present, and in some forms, the body bears flat scales, which somewhat resemble those of *Lepidoptera*. The alimentary system is simple; Malpighian tubules are sometimes absent. The nervous system is of the primitive Annelidan type, though in some groups the abdominal ganglia are wanting, or are fused with the last thoracic ganglion. The tracheal system is often little developed, being sometimes entirely absent. Remarkable variations exist in the form of the genitalia, especially in the *Thysanura*.

Apterygota occur in a variety of situations, but, speaking generally, *Thysanura* are found more abundantly in warm regions and dampness is not an essential feature of their surroundings, while *Collembola* seem to prefer temperate regions and are always found in damp situations.

Their economic importance is very slight; a few *Thysanura* are minor household pests, and some of the *Collembola* damage roots and seeds of plants.

PROTURA

Myrientomata. Anamerentoma.

Antennæ absent. Three pairs of abdominal appendages. Twelve abdominal segments.

In distribution, the *Protura* are both temperate and tropical.

Possibly the most primitive group of the *Aptera*, they are minute, white, soft-bodied insects, the largest being two millimetres long, and many being so small as to be almost invisible to the naked eye. They possess no antennæ, being in that respect unique amongst all known insects. The fore-legs are generally held up over the head, appear to be antennæ at first sight and probably function as such. The head is

FIG. 1.—*Acerentomon* sp. (× 25.)
(After Berlese.)

rather small, coming to a point in front; the mouth-parts, which are withdrawn into the head (entotrophic), consist of a pair of styliform mandibles, a pair of maxillæ, and a labium, the latter two bearing palps; the maxillary palps are large and can be seen projecting from the head at each side. No true eyes are present, but there is a pair of what Berlese calls "pseudocelli" near the front end of the head. Becker believes these to be related to the post-antennal organs of *Collembola*, and suggests that they respond to vibrations. The legs are short, with a single claw on the tarsi; the fore-legs are rather longer than the others

and serve for tactile purposes, to replace the antennæ, being provided with special sense-hairs for the purpose. The abdomen consists of twelve segments in the adult state, a greater number than is present in any other mature insect. In the earliest embryonic stage, as far as is known, nine segments only exist and the remaining three are interpolated one at a time between the last and penultimate segments, as the process of growth continues. Certain paired appendages occur on the first three abdominal segments, of which the first pair are always two-jointed, and the others either one- or two-jointed. No anal cerci are present, the final segment of the body being truncated—from which fact the name Protura is derived. The sexes can only be distinguished by a study of the genital system.

The head and prothorax of some contain certain small, dark, rounded structures termed "concretions" by Rimsky-Korsakow; these are disposed symmetrically—five pairs in the head, and three pairs in the thorax. Their function is not known. The alimentary system is simple, possessing a long mesenteron; six short Malpighian tubules occur. A pair of glands opens on the eighth abdominal segment.

The nervous system is of the typical Annelidan form, possessing six pairs of ganglia in the abdomen. Certain supplementary ganglia are also present at the base of each leg. No tracheal system occurs in some forms, while others possess two pairs of spiracles, on the meso- and meta-thorax. Prell states that the tracheæ from the mesothoracic spiracle supply the head, thorax, and two hind pairs of legs, while those from the metathoracic pass to the abdomen and hind-legs. In the female, the genitalia consist of two straight simple ovaries with oviducts which pass back ventrally from the metathorax, uniting in a short vagina opening between the eleventh and twelfth segments. The male possesses two large testes joining anteriorly at the metathorax; from these pass long, coiled vasa deferentia to the protrusible penis situated between the eleventh and twelfth segments.

Of the life-history extremely little is known. No deposited eggs have yet been discovered, but their relatively large size as seen in the oviduct suggests that they are laid only a few at a time. Larval forms have been found, differing from the

adult in possessing fewer segments in the abdomen. There is some uncertainty as to the nature of their food, though it is probably of a soft character, the bark-inhabiting forms probably feeding on sap or plant-tissues, and the ground species on decaying vegetable matter. *Protura* are found under stones, in moss and peat, under the bark of trees, etc. Williams says, "Rimsky-Korsakow describes them as being solitary, and usually I found them only one or two at a time, but on one occasion I obtained fifty from one small block of peat, while Bagnall alludes to finding them in profusion." The best way to collect them is by use of the Berlese funnel. One species, *Protapteron indicum*, was made the basis of a new order, the *Protaptera*, by Schepotieff (1909), who discovered some specimens in preserved decaying palm-fruits in Malabar. But they were found to be merely a species of *Protura*, and the order *Protaptera* has now been abolished. The *Protura* are divided into two families as follows :—

ACERENTOMIDÆ.

First abdominal appendage two-jointed, second and third one-jointed ; tracheal system absent. *Acerentomon. Acerentulus.*

EOSENTOMIDÆ.

All abdominal appendages two-jointed ; two pairs of spiracles, on the mesothorax and metathorax. *Eosentomon.*

Representatives of both families are found in England.

Berlese monographed the order in 1909. Silvestri (1907 and 1909), Börner (1909), and Prell (1911 and 1912), have also written on this order. Bagnall gave a popular account of the group in 1912, and Williams in 1913 wrote a summary of the knowledge then extant.

THYSANURA

Abdomen with ten or eleven segments. Antennæ with many segments. Anal cerci present. Abdominal styles present.

Thysanura are confined mainly to tropical regions, very few being found in temperate lands.

They are small, white or greyish, soft-bodied insects, recognizable by their long, many-jointed antennæ and anal cerci. The body is narrow and flattened, varying in length, over all, from a quarter to three-quarters of an inch, and is covered with scales or hairs.

The head, which is well marked, is sometimes partly concealed by the prothorax. Eyes may or may not be present. The biting mouth-parts are drawn into the head (entotrophic) in some forms, while in others they are situated externally as those of normal mandibulate insects ; they consist of labrum, mandibles, maxillæ and maxillary palps, hypopharynx, labium and labial palps.

Three distinct segments are present in the thorax ; the legs are moderately long, and bear two claws on the tarsi ; in one family a small, cylindrical appendage, resembling those on the abdomen, occurs on the basal segment of the last two pairs of legs. The abdomen is flattened with ten or eleven segments either nearly equal or gradually tapering posteriorly. Abdominal appendages occur in all forms, consisting of a series of styles and protrusible, tube-like, vesicular structures, varying in arrangement in the different groups. The sexes in *Thysanura* are distinct. In the female, the ovipositor consists of four elongated, cylindrical, rod-like appendages, of which the two anterior proceed from the eighth, and the two posterior from the ninth segment. The male possesses a broader and shorter spatulate process on the ninth segment.

Salivary glands are present in all forms. The alimentary canal is straight and simple ; a gizzard containing horny teeth is sometimes present.

Malpighian tubules are present in some forms, while in others their place is taken by a ring of large glandular cells at the posterior end of the mid-gut; in one family there is apparently no special secretory apparatus.

The nervous system is Annelidan in form, supra- and sub-œsophageal ganglia being present in the head, connected with ganglia in each division of the thorax, and in the first seven or eight abdominal segments. There are three to ten pairs of spiracles, the thorax always possessing a pair in each segment; the prothoracic are the largest; some species of *Japyx* are stated to have four pairs in the thorax. An ostiate heart is present.

The genitalia of this order are extremely interesting and peculiar. The two ovaries are either simple or give off a number of short egg-tubes (ovarioles); in all cases the oviducts unite and open between the eighth and ninth segments. The testes resemble the ovaries, being simple or compound, and also opening at the end of the eighth segment; the vasa deferentia may be short or long and coiled.

Thysanura are found always in concealment, inhabiting the soil, peat, moss and decaying vegetable matter. Some are found only in houses and a few live on rocks by the sea-shore.

Extremely little is known of the habits and life-history. The eggs are white, and generally laid singly, and hatch into nymphs much resembling the adult; in this order there is no post-embryonic increase in the number of abdominal segments. The group as a whole are scavengers, but may be predaceous.

The chief authorities on the order are Berlese, Silvestri, Bagnall and Carpenter. Lubbock monographed the *Thysanura* in 1873. Other works are those of Grassi and Oudemans (1888), Willem (1899), Escherisch (1903 and 1905), Silvestri (1905), Hilton (1917—nervous system), and Hansen (1917—sense organs).

In 1919, eight British species had been recorded. In addition Bagnall has divided *Campodea staphylinus* into several species. The members of this order are of little economic importance. *Lepisma* and other allied genera eat the glaze of photographs and starchy substances and feed on paper.

The order is divided into five families—*Campodeidæ*, *Projapygidæ*, *Japygidæ*, *Machilidæ*, and *Lepismidæ*.

Campodeidæ.

Mouth-parts retracted. No median process. Generally no eyes. Eleven abdominal segments.

The Campodeids are a family widely distributed in temperate regions, but rare in dry, hot climatic regions.

Fig. 2.—*Campodea* sp. (× 15.)

Small, white, delicate insects, resembling minute centipedes as they wind their way sinuously among the particles of soil in which they live, they are conspicuous for their long cerci, large heads, and hairy bodies.

They possess long, well-developed antennæ, and their eyes are usually absent. As in predaceous insects, the mouth-parts are prognathous (pointing forwards). The mandibles are curved and dentate, the maxillary palpi one-jointed and less developed than those of the other families.

The thoracic segments are distinctly marked; there are no scales on the body, and the abdomen tapers only slightly, the last segment bearing a pair of large anal cerci and no median appendage. Abdominal appendages are situated on the first to seventh segments; on the first is a pair of "uropods" or vestigial abdominal legs; one sac and one stylet are present on each side in abdominal segments two to seven.

No Malpighian tubules occur in this group, their place being taken by a ring of sixteen large, glandular cells. Only seven abdominal ganglia are present; the spiracles are confined to the three divisions of the thorax. Nine pairs of ostia occur in

the heart. In this family, the genital organs are of a much simpler and more primitive form than those found in the other groups. The ovary is merely a long, straight tube running down the side of the body. The testes resemble the ovaries and pass into a short vas deferens.

These small insects, of which there are three genera, *Campodea*, *Entrichocampa*, *and Lepidocampa*, may be found in soil and decaying vegetable matter, in moss, in wood, under the bark of trees, among dead leaves, etc. They are probably predaceous, and are of no economic importance. According to Bagnall, there are several British species, of which *Campodea staphylinus* is the best known.

Prójapygidæ.

Mouth-parts retracted. Anal cerci segmented. No median process. Generally no eyes. Eleven abdominal segments.

This family was founded for one species, *Projapyx stylifer*, from West Africa, by Cook (1899). It occupies a position intermediate between the Japygids and the Campodeids, which are the most primitive of *Thysanura*. By some authors they are considered to be the most primitive of all the insects, but that position is undoubtedly held by *Protura*. They are found only in warm countries. The antennæ are stouter than in the Campodeids, and there are usually no eyes. The body bears no scales ; the eleventh segment is reduced and covered by the tergum of the tenth. Two rather short anal cerci occur, of fewer segments than those of *Campodea*. Abdominal appendages are present on segments one to seven, the first bearing a style and a pair of conical processes on each side, while the remainder have only a style.

Seven pairs of abdominal ganglia occur, and there are seven pairs of spiracles in the abdomen. The ovary possesses ovarioles. The heart has nine pairs of ostia. Silvestri (1905) has written about this group.

Japygidæ.

Mouth-parts retracted. Abdomen ends in a pair of forceps. No median filament. Generally no eyes. Apparently ten abdominal segments, actually eleven.

These insects are confined entirely to tropical countries. They are small, white or brown, having a smooth body with few hairs, a long, distinctly segmented abdomen, and the cerci modified to form a characteristic pair of forceps.

The antennæ are large and hairy; eyes are usually absent. Curved, dentate mandibles and two-jointed maxillary palps are present. The thorax is well marked; the legs are slender and covered with hairs. The abdomen tapers at both ends; appendages are found on the first to the seventh abdominal

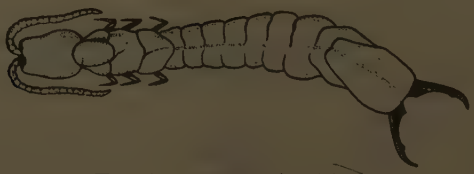


Fig. 3.—*Japyx.* (× 8.)

segments, being more rudimentary than in the *Campodeidæ*; they consist of a pair of hairy papillæ and a short style on each side.

The alimentary canal includes a large cylindrical stomach and a short intestine; no gizzard is present. There are no Malpighian tubules nor apparently anything to take their place. Eight pairs of ganglia and seven pairs of spiracles occur in the abdomen. An extra pair of spiracles is present in the prothorax—the only case known in Insects of the thorax possessing more than three pairs.

The arrangement of the genitalia is more primitive than that of the other families, the ovaries consisting of a pair of egg-tubes in each of the first seven abdominal segments; these join a common duct on each side. The male organs consist of a single pair of sacs, each with a cæcum at its base, and long coiled vasa deferentia.

These tropical insects, which include a number of genera

such as *Japyx*, *Parajapyx*, and *Evalljapyx*, occur generally in damp, decaying vegetable matter. In habits, they may be predaceous.

Silvestri has recently described new species. None are British.

Machilidæ.

Bristle-tails.

Mouth-parts exserted. Median process present. Compound eyes. Eleven abdominal segments.

These insects are widely distributed in both temperate and tropical regions. They are small, quick-moving creatures, covered with scales or hairs.

The head is rather small, bears long antennæ, and is somewhat compressed laterally. Large, contiguous, compound eyes are present. The mouth-parts are hypognathous, i.e. pointing downwards, and are rather delicate in structure, resembling those of *Collembola*. Elongate, slender mandibles occur which are only slightly toothed, while the maxillæ bear palps which are long and seven-jointed.

The prothorax is divided from the rest of the body by a deep constriction. Legs of moderate length occur; on the coxæ of the second and third pairs are appendages resembling those found on the abdomen. The body is sub-cylindrical and tapering, generally covered with flat scales. In the abdomen, the dorsal plates overlap the ventral. A pair of anal cerci, shorter than in *Lepisma*, are situated at the end of the abdomen, together with a long, many-jointed, median process. In addition, there are sub-abdominal appendages on the second and ninth segments; in this family, these attain perhaps their highest development.

The members of this family are generally capable of springing. Females may be distinguished from males by the possession of an external ovipositor.

The alimentary canal consists of pharynx, œsophagus which gradually dilates to form the proventriculus, bearing horny teeth, the true stomach, narrow ilium and rectum. Twelve elongate Malpighian tubules arise from the posterior end of

the stomach. There are eight pairs of abdominal ganglia. Eight pairs of abdominal spiracles are present. The heart has nine pairs of ostia. The ovaries consist of seven egg-tubes, opening into a common duct on each side of the body: though this is a primitive character, the arrangement of the tubes is not strictly segmental. The organs comprise, on each side, three dilated sacs with long vasa deferentia of curious form, joining a common duct.

The young differ very little from the adult, the eyes being compound even in the youngest stages. This family contains a number of genera, of which *Machilis* is the commonest. They are probably all scavengers, feeding on decaying vegetable matter.

Machilis maritima is commonly found on rocks on the English coast, *M. polypoda* occurs amongst dead leaves. Others are found under loose stones. *Assmuthia spinosissima* and *Platystelea barbifer* live in termites' nests in India.

Lepismidæ.

Mouth-parts exserted. Median process present. Eyes simple, when present. Eleven abdominal segments.

Though widely distributed, more tropical than temperate species have been recorded.

In some ways, this is the most advanced group of the *Thysanura*. The body is generally covered with flat, silvery scales, which may, however, sometimes be absent. By this character and by their movements they may be easily recognized.

A small head is present, which is dorso-ventrally flattened and which bears a pair of large antennæ; the eyes consist of a group of a few ocelli. Prognathous mouth-parts occur; the mandibles are short and strong, the maxillary palps well developed and five-jointed. The thoracic segments are very distinctly marked, and larger than those of the abdomen. A gradually tapering abdomen bears at the end two anal cerci and a median appendage. Sub-abdominal appendages occur on the eighth and ninth segments (*Lepisma*), or on the

econd to ninth (*Nicoletia*). An ovipositor is present in the emale, of the same form as that found in *Machilis*.

The digestive system resembles that of the *Machilidæ*, the izzard possessing six horny teeth. Six elongated Malpighian ubules occur. There are eight pairs of abdominal ganglia, nd eight pairs of spiracles are present in the abdomen. Nine pairs of stia occur in the heart. In the emale Lepismid, the genital organs much resemble those of *Machilis* in orm, but five egg-tubes are present n each side, and the arrangement is egmental in the young state, though n the adult this segmentation is lost. The testis of the male consists of three aclike structures opening into a common duct. Nocturnal and gregarious n habit, these insects are found mainly in houses and include *Lepisma* nd *Ctenolepisma*, which latter in ndia feeds on paper and the gummy natter which gives the glaze to its urface. *Ctenolepisma* lays white, oval ggs.

Fig. 4.—*Lepisma* sp. (× 4.)

Lepisma saccharina, the Silver-fish nsect, is commonly found in houses n England. Cornwall describes the ife-history, anatomy, and internal auna of a Lepismid (*Ind. J. Med. Research*, III, i, p. 116 (1915). *Thermobia furnorum* lives in warm corners f the house, and in such places as akehouses, where the bakers refer to it as the "fire-brat."

The family as a whole are of very little economic importance, hough *Lepisma* and *Ctenolepisma* are reported to cause amage to photographs, in the tropics, by eating the glaze omposing the surface.

COLLEMBOLA (Spring-tails)

Abdomen with not more than six segments. Antennæ with few segments. No anal cerci. Ventral abdominal tube present.

Collembola are widely distributed, though mainly found in temperate regions. They are small, active insects, generally dark-coloured, sometimes white, many being prettily marked in various shades of green, yellow, or blue. They possess a ventral sucker on the abdomen and also usually a springing apparatus or furca; the leaps appear to be made at random, being repeated till the insect feels itself to be in a position of safety. One of the most curious characters of this order is the possession of at the most six segments in the abdomen, for all other known insects in the mature state have at least ten.

The head is always large and extremely well defined; in some groups it is partially covered by the prothorax. The antennæ are well developed and generally large, and consist of from four to six joints. In some species, specimens are frequently found with a greater number of joints in one antenna than in the other, and the length of the joints varies considerably; this disparity is due to the fact that the antennal joints, when broken off, are never replaced by fresh ones. Eyes are generally present, each consisting of a group of a varying number of ocelli; they appear as a dark patch on each side of the head.

A very remarkable structure occurs in some *Collembola*; this is the pro-stemmatic or anteocular organ, termed by Sir John Lubbock the post-antennal organ, since it is present in some forms possessing no eyes. It consists of a series of dark patches arranged in a circle, and is situated behind the antenna on each side. But little appears to be known of its structure or function. The mouth-parts are retracted within the cavity of the head and consist of labium, mandibles, maxillæ with palps, maxillulæ of delicate build, hypopharynx and labium, the labium bears no palps.

The thorax is not distinctly separated from the abdomen;

of its divisions, the prothorax is the shortest, and is sometimes completely covered by the mesothorax. Moderately long legs are present, the tibiæ in some species terminating in two claws, in others in one claw; there are no tarsi. Hairs, which are sometimes clavate in form, and in a few species scales, cover the body. The body in shape is either long and cylindrical or short and globular.

Beneath the first abdominal segment is situated a ventral tube or sucker. In some genera it is a simple tubercle divided into two halves; in other forms it is further developed, being enlarged and divided distally into two lobes, while in one group the insect is capable of protruding from the end of the sucker a pair of long, delicate, glandular tubes. This organ is undoubtedly used for adhesive purposes, to give the insect a firmer grip on the surface to which it clings; this function is probably assisted by the secretion of a viscous fluid which the sucker contains. The large saltatorial appendage or furca occurs on either the penultimate or ante-penultimate segment, but is not homologous in the various groups. It consists of a basal joint and a pair of arms, which are simple or two-jointed and generally serrated on the ventral surface to ensure a secure grip on the ground in the act of leaping. In most groups, it is turned forwards, and in some lies within a median groove. A curious appendage, the so-called "catch" or retinaculum, horny, and in most cases two-jointed, bearing two arms, holds the furca in place when not in use; it is generally situated on the third abdominal segment. The ventral tube, retinaculum and furca are all modified vestiges of the abdominal legs occurring in more primitive orders such as the Crustacea.

Salivary glands are probably present. The digestive system is straight and simple; the lining of the œsophagus is chitinous and thrown into folds. Amœbocytes occur in the stomach, which often contains Gregarines. Malpighian tubules are wanting. In the nervous system, the abdominal ganglia are absent, or are fused with the last thoracic ganglion; the heart is ostiate. The tracheal system is of slight development, but varies in the different groups; in some forms no special respiratory organs occur at all. Spiracles, when present, are situated also in the head, one pair occurring there in *Sminthurus*. The genital organs are of very simple structure, and similar

in both sexes. They consist of a single tube on each side of the body, commencing at the anterior end of the abdomen and passing back to open in the fifth segment. A narrow vagina is present in the female, which also possesses small globular accessory glands. The testes unite posteriorly in a triangular receptacle—probably the spermatheca—from which a short, narrow vas deferens passes to the ejaculatory duct, which latter opens, as in the female, on the fifth abdominal segment.

Eggs are laid either singly or in batches of from fifty to a hundred under bark of trees, dead leaves, etc. They are smooth when first laid, but in some cases, according to Lubbock, they later develop hairs on the surface. In a description of the life-history of *Isotoma Walkerii*, Packard states that the eggs are round and glistening white, and are laid on the under-side of bark. The young hatch out in from six to ten days. On hatching, the young nymph is perfectly white and very active ; it is then about ·01 of an inch in length and is relatively shorter and broader than the adult ; it has a stout, short spring, while the head is rounder in form and the antennæ are thicker ; in fact, it resembles the adults of lower forms such as *Lipura*. After the first moult, it is ·025 of an inch long, and still white in colour. A second moult takes place, and the insect then becomes of a purplish hue and more slender in build, now closely resembling the adult. (It is to be inferred from Packard's account that at least a third moult occurs before the adult stage is reached.)

Collembola are found in great numbers in almost any damp situation. Many live in loose earth, among dead leaves, under bark ; some live in houses, some on the leaves of plants ; others are found on the surface of still water, while certain species are known on snow in the Arctic regions. A number of species are myrmecophilous, being found in the nests of some ants ; these forms are always blind and without saltatory appendages.

The chief authorities on this order are Silvestri, Nicolet, Bourlet, Folsom, Bagnall, Carpenter, and Imms.

Lubbock monographed the *Collembola* in 1873. Börner wrote a monograph of the family Neelidæ in 1906, in *Genera Insectorum*, Fasc. 45. Other important works have been written by Willems (1899), Collinge (1910), Quiel (1915)

rampton (1916), and Folsom. The number of British species ecorded up to the present is about 100.

Collembola (mainly *Sminthuridæ*) cause direct damage to ne roots and seeds of plants by feeding on them, and by thus xposing them to the attacks of Fungi. *Achorutes* is an im-ortant pest in mushroom-houses, as it becomes extremely bundant and then disfigures the mushrooms.

Other cases are recorded of damage to growing plants: nese are really rare: *Sminthurus* has been found abundantly n spinach and beans; but that does not imply real damage. There may be cases of damage, chiefly due to the superficial ceration of the tissue, which admits other disease; but these re unusual.

Collembola are subdivided as follows:—

Arthropleona—Achorutidæ, Entomobryidæ.
Symphypleona—Smynthuridæ, Neelidæ.

ARTHROPLEONA.—The head is directed forward or ownward. The post-antennal organ is usually present. The ntennæ are four- to six-jointed, the body is more or less cylind-ical in form.

Achorutidæ.

Furcula short, when present. Scales never present.

These small, crawling insects are white, pink, or blue in olour and slow in movement, being conspicuous by the fact hat they do not leap as do the rest of the *Collembola*. The ody is broad and rather flat, bearing hairs but no scales.

The head is dorso-ventrally flattened and is directed straight orwards. Eyes are usually present; the antennæ are broad nd rather short. There is little distinction between the horax and abdomen; the legs are short and possess generally wo claws, though in some cases only one claw is present. There re no scales on the body, which is usually granular, while the egments of the abdomen are clearly defined. The furcula, hen present, is situated on the fifth segment and is quite hort; its absence in such genera as *Lipura* and *Anoura* is ccompanied by loss of the retinaculum. The last segment

of the abdomen in some forms bears a pair of short upturned hooks. In *Anurida*, the secretions of a pair of head glands pass along a groove between the legs into the ventral tube, assisting in its function of adhesion. The female is usually larger than the male. Included in this family are the genera *Achorutes* and *Lipura*, found mainly in decaying vegetable matter, *Anurida*, including *A. maritima* which lives on rocks by the sea-shore, and *Podura*, of which *P. aquatica* is found on the surface of standing water. *A. maritima* lays eggs in the crevices of the rocks and probably has many moults.

FIG. 5.—*Tomocerus* sp. (× 30, about.)
(*sp.* = spring. *vt.* = ventral tube.)

ENTOMOBRYIDÆ.

Furcula long. Scales present in some.

The members of this family are active creatures, running about and leaping vigorously when disturbed; they include some of the largest forms of *Collembola*. The body is cigar-shaped, the sides being sub-parallel. Scales are generally present, clavate hairs often occur, while the furca is very much larger than in the preceding family, and in some species of *Isotoma* is situated on the fourth abdominal segment. The head is directed obliquely downwards and is often partially

metimes wholly, concealed by the pronotum. Two claws e always present on the tarsi. There is no tracheal system. *otoma* occurs often under bark, though *I. aquatilis* is found the surface of ponds. *Orchesella* and *Tomocerus* are other nera. *Cyphoderes* (*Beckia*) is blind and is found in the nests some ants. *Heteromuricus cavernicclus* occurs in moles' sts and is also blind. As is the case with all *Collembola*, ese insects are always found in damp situations.

SYMPHYPLEONA. The head is usually vertical in sition, i.e. points straight downwards; the antennæ, almost ithout exception, are four-jointed and elbowed. In form, e body is short and globular, the thoracic and abdominal gments closely united. Protrusible tubes occur in the ven-

FIG. 6.—*Papirius* sp. (× 50, about.)

al sucker. No scales are present, the body being generally ly sparsely pilose. The heart extends back only about a ird of the length of the abdomen and possesses only two tia.

SMINTHURIDÆ.

Antennæ inserted on hinder portion of head. Coxæ as ng as, or shorter than, the trochanters. Eyes usually esent.

A globular body with somewhat flattened sides character- s these small insects. They have a large head with long, ır-jointed, elbowed antennæ. Long, rather slender legs are esent, and the furca occurs on the fifth abdominal seg-

ment. Quite a well-developed tracheal system exists, especiall in *Sminthurus* and *Sminthurides*, with a pair of spiracles in th head.

Papirius was originally placed by Lubbock in a separat family. *Sminthurinus corecus*, a blind species, is found i moles' nests.

Sminthuridæ are sometimes very abundant on the surfac of ponds and tanks. Some occur in spasmodic abundance o plants, and are reported as destroying seedlings : such cases ar rare and unimportant.

Neelidæ (*Megalothoracidæ*).

Antennæ inserted on middle or anterior portion of hea Coxæ markedly longer than trochanters. Eyes absen Body globular, segments indistinct.

This family resembles the preceding one in general extern form, but differs in a number of points. One of the mo characteristic of these is the possession of very short antenn which are only half the length of the head. The body is rath bristly, but bears few hairs except in the anal region ; th metathorax is long, the furcula about twice the length the antennæ, and there are no eyes or post-antennal organ Apparently tracheæ are wanting. The stomach differs fro that of other *Collembola* in consisting of a series of four cha bers. Only the first abdominal ganglion is present, and th tends to become united with the last thoracic ganglion. T maximum length of these creatures varies from ·25 mm. to · mm.

Two genera are recorded, *Neelus* and *Megalothorax* ; th are generally found under bark, amongst dead sticks or in t soil. (*Genera Insectorum*, 1906.)

1.

2.

5.

6.

4.

7.

3.

[*Photos by C. L. Withycombe ; No.* 3 *by E. E. Syms.*

PLATE I. ODONATA, EPHEMEROPTERA, AND PLECOPTERA.

1. *Aeschna cyanea* imago at rest (× $\frac{2}{3}$). Æschnidæ.
2. ,, ,, nymph about to emerge (× $\frac{4}{5}$). Æschnidæ.
3. *Calopteryx splendens* newly emerged, with empty nymph skin (× $\frac{3}{4}$). Calopterygidæ.
4. Cloëon dipterum ♂ subimago (× $2\frac{2}{3}$).
5. ,, ,, nymph (× 2).
6. *Chloroperla grammatica* imago (× $1\frac{2}{3}$). Perlidæ.
7. Perlid nymph (× $\frac{1}{2}$).

[*To face p.* 20.

PTERYGOTA

Insects winged in the adult stage, or if wingless, derived om winged ancestors.

PLECOPTERA (*Perlaria*, *Platyptera*), Stoneflies.

Wings membranous and reticulate. Fore-wings narrow. ind-wings generally much broader and with a large plicate ıal area, folded fan-like when at rest. Antennæ long. oxæ small and separated. Anal cerci present, as a rule.

Stoneflies (Plate I, Fig. 6) are recorded from most parts of e world, but are only found in the vicinity of water. As a le they are dull and unattractive flies, of medium or fairly rge size, generally brown or blackish in colour; some *usthenıidæ*, however, are brightly coloured. They can often n rapidly and might at first sight be taken for beetles, though e fore-wings are not chitinized as elytra. When closed, ere is a distinct square shoulder noticeable to the fore-wings. ne hind-wings are folded fanwise under the fore pair when at st. Flight is slow.

The head is of quite large size, with long, filamentous, many-inted antennæ. There is a pair of ill-developed compound es, and three, more rarely two, ocelli. Mouth-parts are of nple biting type in some, but in others they are so reduced to render feeding in the adult state impossible. The mand-les in such cases may exist merely as small fleshy or mem-anous lobes. Maxillæ are also often reduced, but the five-inted maxillary palpi are always present and well developed. ne labium varies in form, but as a rule possesses three-inted labial palpi. The prothorax is free, squarish, and well veloped with a large flat notum. Meso- and meta-thorax ar wings. In the sternites of the thoracic segments are slits vered by membrane. Legs are slender with a three-jointed rsus and two tarsal claws. The wings are usually fully veloped, though in some species the males are micropterous.

Venation is variable, especially in the position and numbe of cross-veins. The hind-wings are generally much larger tha the fore-wings, due to the expansion of the anal area, whic is folded when the wings are at rest, as in the Orthoptera. curious feature of the hind-wing venation is that the radia sector is, in the imago, attached to the media instead of to th radius. The abdomen is often provided at its extremity wit filamentous, many-jointed cerci. Males are smaller than th females.

In *Perla* the alimentary canal is fairly simple, but not o usual pattern. The œsophagus is of considerable size, ther being no crop or gizzard, except in the larva. From th anterior portion of the stomach a lobe is given off on each sid and there are also eight smaller sac-like diverticula. Th stomach is quite small posteriorly, and at the commencemen of the intestine, which is short and straight, are inserted fro twenty to sixty Malpighian tubules. Two pairs of larg salivary glands are present. This type of digestive syste is not constant in the *Plecoptera*, but varies considerably i complexity. The reproductive organs are peculiar in that th ovaries or testes are connected together anteriorly so as t form an arch. Vesiculæ seminales may be present or absen

After pairing, the eggs as extruded collect in a mass at th end of the abdomen and may be thus carried about for o hour or one day by the female. They are then at some tim washed off into the water. Here the eggs separate and trav with the current of the stream a short distance. As soon the glutinous cap at the micropylar end comes into conta with a solid object it adheres and thus eggs may be fou attached to stones, etc. The egg of *Perla* is about ·5 m long, dark brown in colour, and oval or vase-shaped. Occ sionally there is a circular ridge surrounding it at the e opposite to the micropyle, otherwise the chorion is witho ornamentation. About 1,600 eggs may be laid by a sing female in three or four masses. Pairing takes place in betwe each successive oviposition.

The nymph (Plate I, Fig. 7) is somewhat similar to the ima in the shape of the body, but wings are of course not prese except as rudiments in later life. Mouth-parts are well dev oped and of biting type. Tracheal gills are present, and a

commonly filamentous, in tufts; less often foliaceous (*Nemoura*). They vary in position, being sometimes placed on each side of the thorax, or on the sides of the abdomen, or at the base of the caudal stylets on either side of the anus. In the adult, gills often persist in reduced form. The legs are long, flattened, and fringed with hairs, well adapted for swimming or running. There are two tarsal claws. At the posterior end of the abdomen a pair of slender, many-jointed cerci are nearly always present.

The nymphs are mainly carnivorous, feeding on Chironomid and *Simulium* larvæ, but there is good reason to believe that some of the smaller species are herbivorous, judging by the contents of the alimentary canal. Owing to its long fringed legs, the nymph can run and swim rapidly among the stones of the stream-bed. Wings appear gradually. Just before the last moult, the nymph crawls out of the water, the old skin splits, and the imago escapes. The life-cycle as a rule occupies one year, but in some of the larger species probably two or three years. The imagines may appear at any time, from quite early in the year, in some species, until summer. The winter is passed as a nymph in the water. Stoneflies generally inhabit streams; a few may be found in ponds if the water is constantly being renewed.

The majority of stoneflies do not feed in their imaginal state, but some species of *Tæniopteryx* have well-developed mouth-parts and feed on the young buds and foliage of river or brook-side trees. In 1918, E. J. Newcomer recorded *Tæniopteryx pacifica* as a pest attacking the buds and blossoms of peaches, apricots, and plums in the Wenatchee Valley, U.S.A. The fruit crop of those trees near the stream was seriously affected.

In *Coll. Zool. Selys*, Fasc. IV, Klapálek has monographed the *Plecoptera* (*Perlodides*). A classification of the order is given by Tillyard in *Canad. Entomol.* 1921.

As British we have twenty-nine species, listed by Morton in *Ent. Mo. Mag.* 1907. A valuable work for British entomologists is that in *Die Süsswasserfauna Deutschlands*, Heft 8, by F. Klapálek (1909).

Tillyard, 1921, recognizes the following families: *Eustheniidæ*, *Pteronarcidæ*, *Perlidæ*, *Austroperlidæ*, *Leptoperlidæ*, *Nemouridæ*, and *Capniidæ*.

EPHEMEROPTERA

(*Ephemerida*, *Plectoptera*, *Agnatha*), Mayflies.

Fragile insects without mouth-parts. Antennæ small. Wings membranous with many longitudinal and cross-veins. hind-wings small, often reduced or absent. There are two, or more usually three, caudal filaments.

Mayflies are to be found in all parts of the world, mainly in temperate regions, but are confined to the neighbourhood of water, not being found in arid districts. They are quite unmistakable insects and of very uniform appearance (Plate I, Fig. 4), occurring generally in abundance where found, near streams or other water. The net-veined delicate wings, of which the fore pair is always the larger, are opposed when at rest, after the manner of butterflies. The tail filaments are also very characteristic. Colours are dingy grey, brown, green, or yellow, never brilliant.

The head is of medium size with large compound eyes and three ocelli. In the male the compound eyes are always larger and frequently divided completely, so that there are really four distinct compound eyes. One pair of these may be still further modified and each eye be borne at the end of a pillar. Antennæ are short, of two or three joints, the terminal one being long and bristle-like, the basal joint short and stout. Mouth-parts are atrophied. Generally there is no trace of mouth-parts, but in some, indications of mouth appendages are present. The prothorax is small. Mesothorax very large and well developed, contrasting with the much smaller metathorax, which is little different in size from an abdominal segment. The wings are somewhat fanlike and longitudinally corrugated, with several intercalary veins and many cross-veins. The fore pair are always the larger, the hind-wings being often small and sometimes entirely reduced. Legs vary in length and are adapted for clinging. Frequently the first pair of the male are of exceptional length and are used in pairing. In *Campsurus* only the first pair of legs is normally developed, the second and

third pairs being reduced to short stumps. There are ten abdominal segments, generally simple, but sometimes with lateral processes as in *Oniscigaster*. The anal cerci are long and filiform, and as a rule the tergum of the eleventh abdominal segment forms a median tail filament. This latter is reduced in such forms as *Cloëon*, which therefore have only two caudal filaments. In the male there are two pairs of jointed styles which serve as claspers. The lower pair of these may be two- to four-jointed (five-jointed in *Oniscigaster*), the upper pair are two-jointed.

In the imaginal state the alimentary canal is filled with air which increases the buoyancy of the insect. The reproductive organs of both sexes are very simple. The two genital ducts are separate for their entire length, with two separate genital pores. There are no accessory glands or diverticula in either sex.

Mayflies dance in swarms usually at dusk or at night; during the dance pairing takes place. The female then lays her eggs, in number from 500 to nearly 4,000, according to species. In some cases the entire contents of the ovaries are deposited at once, the mass distintegrating in the water. In other cases eggs are laid singly and may be attached to stones, etc. The egg is generally of oval shape, white, pale green, or brown in colour, and enveloped in mucus. The chorion may be sculptured, and frequently anchoring processes are present. On hatching, the young larva resembles a *Campodea*. No tracheæ or gills are present in the earliest stages; later gills, and then tracheæ, appear. Growth is gradual, there being, according to Lubbock, at least twenty-three moults.

The nymph (Plate I, Fig. 5) is campodeiform, cylindrical or flattened, more or less tapering at either end. The head is wedge-shaped and pointed in burrowing forms, short and broad in free living species. Compound eyes are present, and a pair of filiform, many-jointed antennæ. The mouth-parts are of biting type, consisting of labrum with epipharynx, mandibles, maxillæ, and labium with hypopharynx. The hypopharynx is well developed in Ephemerid nymphs and consists of a median fleshy lobe with two lateral appendages. In burrowers, each mandible has a tusk developed on the outside, which projects forward. Often these tusks are the most conspicuous

features of the head, as in *Ephemera*. Palpi are often reduced. Generally the thorax is of normal type, but in *Bætisca* and *Prosopistoma* the mesothorax forms a dorsal carapace which covers the gills. The wings develop gradually and externally. The legs bear a single tarsal claw. The abdomen tapers to its extremity. There are seven pairs of lateral tracheal gills, one being borne at each of the postero-lateral angles of the first seven tergites. They vary in form, being filamentous or flattened. They may be exposed, or each protected by a scale-like lobe, or, as already mentioned, the thorax may cover them as a gill chamber. Eaton states that in some larvæ the rectum is also to a certain extent respiratory, as in Dragonflies. At the posterior extremity of the body are three filaments fringed with hairs; these are, however, shorter than those of the imago. The nymphal tail filaments serve for oxygenation of blood, in addition to being used to assist in locomotion.

Food consists mainly of vegetable matter, but sometimes nymphs are carnivorous, e.g. *Chirotonetes*. Just before emergence the nymph rises to the surface and swallows air, which is retained by valve-like structures of the alimentary canal. Soon, while floating near the surface, the nymphal skin splits on the dorsum of the thorax, and in a few seconds the subimago has emerged and flown away. In primitive forms the nymph climbs a support before disclosing the subimago. This subimaginal stage may only last a few minutes, or several days. As a rule a subimago can be recognized by its dull colour, as compared with that of the imago. In two genera, *Palingenia* and *Campsurus*, the female never sheds its skin again, but remains permanently as a subimago. Finally, in normal cases, there is one more ecdysis, and the perfect fly appears in brighter colours and usually with longer tail filaments. The adult takes no food and is very short-lived, some lasting only a few hours, others a few days. Pairing and egg-laying are the sole objects of aerial life. There may be several broods in the year, or the life-cycle may be extended over two or three years.

Mayflies are particularly defenceless in all stages of their existence and are the prey of insectivorous animals both while in the water and out. Economically they are of no importance

except inasmuch as they constitute one of the articles of diet of freshwater fishes, the latter being very partial to these insects in any stage. In Central Africa *Cœnis kungo*, collected in large numbers, is used for human consumption.

Eaton has monographed the order in *Trans. Linn. Soc. Lond.* 1883–88. Morgan gives an account of the biology of Mayflies, with a very complete bibliography, in *Ann. Ent. Soc. Amer.* VI, 1913.

We have about forty British species of Mayflies. A concise work on the forms which are likely to occur in Britain is that of F. Klapálek in *Die Süsswasserfauna Deutschlands*, Heft 8, 1909.

A full account of the nymphs of European Ephemeroptera, as well as Plecoptera, will be found in *Larves et Nymphes aquatiques des Insectes d'Europe*, 1921, by Rousseau.

ODONATA

(*Paraneuroptera*), Dragonflies, Horse-stingers.

Elongate insects of medium or large size, with two pairs of equal or sub-equal net-veined wings. Antennæ small and inconspicuous. Compound eyes large.

Dragonflies are found in all parts of the world, and are so well known that a description is hardly necessary (Plate I, Figs. 1 and 3). The larger forms are powerful insects on the wing and may be seen hunting smaller insects over water or in forest glades. Colours are brilliant as a rule and often metallic. Their significance is possibly warning, in some cases.

The head is provided with powerful biting mouth-parts, the mandibles being thick and strongly toothed. Antennæ are considerably reduced and are filiform. There are two large compound eyes and three ocelli. The prothorax is small and movable, the meso- and meta-thorax being fused as a synthorax. The wings are equal or sub-equal, closely net-veined, and placed far back on the thorax. The subcosta terminates near the middle of the anterior border of wing at a thickened cross-vein, forming a joint, the *nodus*. A pterostigma is generally present near the wing apex. The radius is simple or once-branched. The legs are placed well forward and are adapted for catching and holding prey, being of little use for walking. The abdomen is long, with ten complete segments. In the male there is a complex copulatory pouch in the anterior part of the abdomen, formed from the sternites of segments two and three. At the posterior extremity there are claspers, which serve to distinguish the sexes and also afford valuable specific characters. The genital pore is on the ninth sternite. The female may be provided with an ovipositor; the genital pore is between sternites eight and nine.

The early stages of all dragonflies are passed in water. Eggs are laid in two ways: (1) In plants; (2) In water. Oviposition in plants occurs in those forms possessing an ovipositor, viz. all the *Zygoptera* and also the *Æschninæ* and

Petalurinæ of the *Anisoptera*. The female makes an incision in the tissues of plants in or near the water. In such cases the egg is of elongate form. In those species practising oviposition in water, the female dips her abdomen into the water and drops eggs freely. The egg is rounded. In some genera, e.g. *Sympetrum*, eggs are laid in gelatinous ropes, attached to submerged objects, and containing many hundreds of eggs. The embryology is peculiar, and includes a revolution of the embryo within the egg. After three weeks or less the egg hatches as a pronymph. This stage is of only a few seconds' duration as a rule, and then the second-instar nymph emerges from the pronymphal skin. In *Lestes*, eggs are laid in stems of osiers, etc., and the pronymph on emerging from the stem jumps clear and on to the water before the second-instar nymph appears. There are from eleven to fifteen instars, growth taking place gradually and the wings developing externally.

The nymph (Plate I, Figs. 2 and 3) is shorter and stouter than the imago and aquatic in habits. There are compound eyes, but ocelli are absent except in late nymphal life, and then only in the *Zygoptera* are they clearly visible. Antennæ are filiform and longer than those of the imago. The mouth-parts are of carnivorous biting type as in the imago, but the labium is highly modified to form a flat, elongated, jointed organ of prehension, the mask. The legs are longer and more easily movable than in the imago. The wings develop gradually, externally. In the *Zygoptera* (Plate I, Fig. 3) the nymph has three lamellate caudal gills at the extremity of the abdomen, and in a few genera of this sub-order there may be lateral abdominal gills on segments two to eight. In the nymph of *Anisoptera*, the rectum is barrel-shaped and serves for respiration. There are six longitudinal sets of gills, projecting inwards. Water is drawn in to bathe these gills and it can be expelled rapidly should the animal wish to propel itself suddenly forwards. A gizzard with chitinous teeth is more strongly developed in the nymph than in the adult. The midgut in both nymph and imago has no caeca. There are, in the newly hatched nymph, only three Malpighian tubules, but with growth these increase in number and are finally very numerous.

In all stages (except the pronymph) the nymph is predaceous, capturing smaller insect larvæ, etc., by rapidly shooting out

the mask, seizing its prey, and bringing it back to the mouth to be devoured by the powerful mandibles. Zygopterous nymphs (Plate I, Fig 3) are more delicate and slender than those of the *Anisoptera* ; they generally live among water weeds. Anisopterous nymphs (Plate I, Fig. 2) are stouter in build, without the three caudal gills found in the *Zygoptera*. Nymphs of these usually lurk at the bottom of ponds, or in swamps, concealed in mud or debris, although some are cryptically coloured and have similar habits to the *Zygoptera*. When about to assume the adult form, the full-grown nymph ascends a reed stem, or walks up the bank out of the water, and here, after the nymphal skin has split dorsally, the adult insect emerges, and attains the perfect form.

The imagines hunt insects on the wing and are of value in checking Tabanids, mosquitoes, and other insects living in or near swamps. There have been few records of dragonflies feeding on mosquitoes, but Tillyard records several definite cases observed by him. A slight amount of damage may be caused by the nymphs of dragonflies feeding upon young fish.

There is not more than one brood in the year, as a rule, and often two or three years may be passed as a nymph. Hibernation is generally in the nymphal state, but in some species as egg or adult.

Dragonflies are preyed upon by various insectivorous animals and birds, smaller forms are often devoured by their larger relatives. Minute hymenopterous parasites destroy the eggs.

There are many works on the Odonata : Martin, *Cordulines*, *Coll. Zool. Selys*, Fasc. XVII (1906). Martin, *Æschnines*, *Coll. Zool. Selys*, Fasc. XVIII–XX (1908–9), and Gen. Ins. Fasc. 115 (1911) and 155 (1914). Ris, *Libellulinen*, *Coll. Zool. Selys*, Fasc. IX–XVI (1909–13). Tillyard, *The Biology of Dragon-flies* (1917).

The British species have been described by Lucas, in his book on *British Dragonflies*, 1900. Tillyard, 1917, also gives a condensed account of all the British species.

The number of species recorded in the world is about 2,500, of which 42 are British.

The order *Odonata* is divided into three sub-orders, *Anisoptera*, *Anisozygoptera*, and *Zygoptera*.

The *ANISOPTERA* (Plate I, Fig. 1) are generally of stout build, the wings are held horizontally when at rest, and not with upper surfaces opposed. The venation (Fig. 7) comprises a triangle. Compound eyes are large, often meeting in the mid-dorsal line, never separated by a distance greater than their own diameter. An ovipositor may be present, or reduced. Nymph stout (Plate I, Fig. 2), with rectal gills and no lamellate

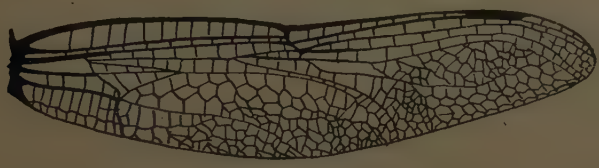


Fig. 7.—Diagram of Anisopterid Wing.

caudal gills. Gizzard with four to eight radially symmetrical fields. There are two families, *Æschnidæ* and *Libellulidæ*, which are subdivided into several sub-families and tribes.

The *ANISOZYGOPTERA* was first established by Handlirsch and includes one remarkable existing genus *Epiophlebia*. Until 1921, when Tillyard described the nymph of *E. laidlawi* from the Himalayas, there was only one species, *E. superstes*

Fig. 8.—Diagram of Zygopterid Wing.

of Japan. *Epiophlebia* possesses some characters of both the orders *Anisoptera* and *Zygoptera*. Anisopterous characters are the shape and build of the body of the imago, the general facies of the nymph, the labial mask and anal appendages. Wing venation is as in the *Zygoptera*. The gizzard is also of zygopterous pattern. There is only one family, *Epiophlebiidæ*, with two species.

The *ZYGOPTERA* (Plate I, Fig. 3) are the slender-bodied dragonflies known as "Demoiselles." Both fore- and hind-

wings (Fig. 8) are equal and closely similar. The "discoidal" cell is quadrilateral, not triangular. Wings held back over abdomen vertically, with upper surfaces opposed when at rest. Compound eyes small, separated by a space greater than their dorsal diameter. Ovipositor always present. The nymph is slender, with three caudal gills, and the rectum, though also respiratory, is devoid of true rectal gills. Gizzard with eight to sixteen radially symmetrical fields. There are three families, *Calopterygidæ*, *Lestidæ*, and *Agrionidæ*.

For an account of the nymphs of European species of Odonata see also *Larves et Nymphes aquatiques des Insecies d'Europe* by Rousseau, 1921.

EMBIOPTERA

Small, elongate, soft-bodied insects, with simple antennæ and short anal cerci. Wings when present are small and equal, with indefinite venation. Mouth-parts mandibulate. Prothorax small, meso- and meta-thorax elongate. Abdomen of ten segments. Gregarious insects, living in silken tunnels.

This order consists of the single family, *Embiidæ*, which was formerly placed in *Neuroptera*, or was grouped with the *Psocidæ* and the *Termitidæ* to form the order *Corrodentia*.

FIG. 9.—*Donaconethis abyssinica*, Enderl. ♀. (× 4.)
(Adapted from Enderlein.)

Embiids comprise a small number of species, about seventy having been described. They are widely distributed in tropical and sub-tropical regions. None are indigenous to Britain, but one species, *Oligotoma michaeli*, has been recorded from a hot-house in London, where it was believed to have been imported with orchids from India.

Embiids are elongate, dark or dull coloured, and very small. In length they seldom exceed $\frac{1}{4}$ in., but the largest known species, *Embia major*, described from the Himalayas by Imms in 1913, sometimes attains a length of $\frac{3}{4}$ in. The head is large and distinct, with compound eyes and long simple antennæ of about fifteen to thirty joints. The mouth-parts are mandibulate with an imperfectly divided labium. The thoracic segments are distinct; the prothorax being much smaller than the two remaining segments. Wings are present in the males of most known species and in the females of a few. There are two

pairs, which are in no way connected. There is no differentiation between fore- and hind-wings: both are long, narrow, and usually smoky-coloured. The venation is weak, and there are very few cross-veins. The thoracic segments do not exhibit any strengthening or fusion for the purposes of flight. The abdomen is long and consists of ten segments: in the female the genital aperture is found on the under-surface of the seventh segment. The external genitalia of the male are situated on the last abdominal segment. They consist of a small conical protuberance, on which the genital duct opens, and a pair of styles, which are asymmetrically arranged on each side of it. In both sexes the last abdominal segment bears a pair of anal cerci. These are short and composed of two joints: like the genitalia, they are asymmetrical in the male. The legs are short and adapted for running, with three-jointed tarsi. In the fore-legs the basal tarsal joint is enlarged and glandular. Silk is produced by both adults and nymphs of both sexes, and it is believed by some authors to be produced from these tarsal glands. Enderlein, however, considers that the silk is produced from glands which open on the labium: the fore-legs are used in spinning operations, and he believes that the secretion derived from the tarsal glands, which is thin and

FIG. 10.—*Donaconethis abyssinica*, Enderl. ♂. (× 4.)
(Adapted from Enderlein.)

vatery, is in the nature of a lubricant, and prevents the silk rom adhering to the legs.

The alimentary canal is well developed. The stomach is ong and slender, without diverticula. In the adult there are wenty malpighian tubules. There is a single tracheal system, vith ten pairs of stigmata, two being situated on the thorax nd eight on the abdomen. The gonads in the male are very arge ; each testis consists of five lobes. There are two seminal esicles and two pairs of accessory glands. The ovaries in the emale consist each of five egg tubes which open into a straight luct.

The Embiids are gregarious, living in damp warm situations n nests composed of silken tunnels, which they weave by neans of their fore-legs. In the tunnels they run rapidly either ackwards or forwards, in the former case apparently using he anal cerci as antennæ. The tunnels are placed under bark, tones, or in other situations where there is abundant moisture ; n Indian species has been found in the sheathing leaves of Bamboo, but only those leaves which have been bored by a Scolytid beetle are so favoured. The food probably consists f vegetable matter. Winged species fly at dusk, and will eadily come to light.

Eggs are laid by the females in the galleries ; they are small, vhite and oval, and hatch to nymphs which are similar to the dults except in size, colour, and lack of wings. They are white t first, gradually becoming darker, and attain full growth in wo or three instars. The female watches over the eggs, and uards the young nymphs at first.

Embiids are of no economic importance. Enderlein recog- izes two families, *Oligotomidæ*, with one genus and *Embiidæ* vith eight genera. He describes sixty species, but others have ince been described by Imms (1913), and Navas (1916).

The more important authors are: Hagen (monograph), 885 ; Grassi, 1893 ; Enderlein, 1909 ; Enderlein (monograph), 912 ; Krauss (monograph), 1911.

ORTHOPTERA

First pair of wings, or tegmina, thickened, with parallel sides. Hind-wings are membranous, folding fanwise under tegmina, but both often absent. Mouth-parts biting, anal cerci always present, and metamorphosis slight and gradual.

The Orthoptera form a large and important order of fairly uniform character. It is composed of comparatively large insects, none being very minute, while some of the largest are included. Flight as a whole is not a marked feature, and in some the alar organs are useless for flying purposes and may be used solely for the production of sound, which is a feature of some of the families. The colour is usually cryptic but protective, deceptive and warning coloration is abundant. Mimicry of plant-structure is especially well developed in the *Phasmidæ*, and several young forms mimic insects of other orders. A Sudanese member of the family *Locustidæ* is specially formed to simulate an ant.

The order is more tropical than temperate, but is, nevertheless, very well distributed.

The body structure is primitive, all segments being clearly visible with little fusion. The prothorax is free and the other thoracic segments well defined. There are ten abdominal segments, with part of the eleventh, the ninth segment carrying the genital aperture, and the tenth the anus as well as the segmented cerci. The male may be provided, in addition, with a pair of styles. The mouth-parts are hypognathous and mandibulate with either blunt or sharp mandibles according to the habits. There is a large labrum, the palpi are well developed, and a hypopharynx formed into an efficient tongue. The maxillæ are slightly reduced, and the labium is divided medianly. The head is large, capable of considerable movement in some, and bears the compound eyes, simple antennæ and generally ocelli. The tegmina are coriaceous and may not be used in flight; when at rest they are folded over one another flat along the back. The hind wings vary greatly in colour from the tegmina, especially in females, and have nervures radiating from the point of attachment with short cross-veins

orming a network. In the leaf-simulating species the veins f the tegmina are arranged in such a manner as to resemble xactly the veins of the actual leaf. The legs are long and ormed either for running or jumping. The female may be rovided with an ovipositor and is generally larger than the nale. Where there are sound productive modifications, the nale is generally the only one possessed of them, but there re exceptions. These sound producing organs, which are haracteristic of the *Acridiidæ*, *Locustidæ*, *Gryllidæ*, are pecial modifications of the part of the body on which they re situated. In some members of the *Locustidæ* the tegmina re used solely for the production of sound, and the pronotum nay be enlarged so as to protect them without in any way rresting their action, giving a peculiar hooded appearance to he insect. When the stridulating organ is situated on the body, he latter may be specially enlarged so as to facilitate the pro- luction of a greater volume of sound. The function of the strid- ulating organs is largely that of a secondary sexual character.

The alimentary system is not complicated, and may be rovided with a large crop and a gizzard with horn-like ridges. alivary glands and receptacles are usually large, and the Malpighian tubules numerous. According to Heymons there re originally eleven pairs of ganglia, of which three are thoracic, ut the eleventh soon becomes merged into the tenth. In a ew the tracheæ are fitted with numerous reservoirs. Repro- uction by means of fertilized eggs is general but not universal. Eggs may be laid singly or in cases containing one or many. Periods of development in the egg vary from three weeks in he tropics to eight or nine months in colder regions, but as a hole they may be said to be long. The embryo is provided ith a large quantity of yolk, and breaks the egg-shell on atching by means of an egg tooth on the head.

The young nymph is similar to the adult, but softer, of a ifferent colour and always wingless. There is a uniform uccession of about five ecdyses with an increase of size after ach one. The wings usually appear at the second, accom- anied by some modification in the structure of the thorax. he imago, which is active and long-lived, is either herbivorous r carnivorous, but a few may partake of both varieties of food. ibernation is almost always in the egg stage. The habits are

quite uniform, only one species bores into plants, and only a few are truly aquatic. The majority either burrow or lead free lives on the surface of the ground. The various natural enemies will be more conveniently dealt with under the separate families.

Of the older authorities on the group, Brunner von Wattenwyl, Saussure, and Redtenbacker may be consulted when necessary. The principal modern publications may be looked for under the following names and dates: Tumpel (1901), Kirby's Catalogue (1904), Schwabe (1906), Caudell (1907), Ruthven (1911), Caudell (1911). Caudell (1916 and 1917), Lucas, *British Orthoptera* (1920). Bolivar is the present European authority whose works should be consulted.

Lucas gives thirty-one species as indigenous to Britain, eight naturalized aliens, and a number of casual visitors. On the whole this country is not very well provided with members of the order. There are some five hundred species in Europe, and the world species probably number ten thousand.

The economic importance of the group is centred in the family *Acrididæ* which contains all the locusts which have been recorded as serious plagues since the dawn of history. Other families have some importance, but it is overshadowed by the devastating powers of locust swarms.

The order was divided into two groups, the *Cursoria* with four families, and the *Saltatoria* with three. The families which were classed among the *Cursoria* are very distinctly divided one from another, while in the *Saltatoria* they are much more closely allied; indeed it is extremely difficult to place some species definitely in one family or the other, and this group will no doubt be split up into a greater number of families when it has been studied more.

We have adopted the classification, whereby *Forficulidæ*, *Arixenidæ*, and *Hemimeridæ* may be a separate order, and also the inclusion of *Grylloblattidæ* nullifies the distinction of *Cursoria* and *Saltatoria*; nature unfortunately works in degrees and not in clean-cut divisions, so we adopt the system of seven families, not divided into two groups. It is with reluctance that we place *Hemimerus* with *Dermaptera*; it is probably linked to *Blattidæ*; but no mechanical system dealing with groups in sequence can adequately express the relationships of evolved forms: the student may remember

that probably *Dermaptera* are closely linked to *Orthoptera*. The following is the family sequence adopted, and the diagnostic characters of the families :—

Blattidæ. Running legs. Large coxæ. Head concealed under pronotum. No external ovipositor. Cerci jointed. Male with styles.

Mantidæ. Long raptorial fore-legs. Long pronotum. No external ovipositor. Cerci jointed. Male with styles.

Phasmidæ. Long clinging legs. Prothorax short. Cerci not jointed. No ovipositor, but ventral processes.

Acridiidæ. Jumping hind-legs. Cerci jointed. Two pairs of digging processes in female. Tarsi three-jointed. Antennæ short. Auditory organ on abdomen.

Locustidæ. Jumping hind-legs. Cerci not jointed. Ovipositor of three pairs of processes, usually laterally compressed. Male with styles. Antennæ long. Tarsi four-jointed. Auditory organ on fore tibia.

Grylloblattidæ. Running legs. Cerci jointed. Ovipositor of three pairs of processes, asymmetric. Tarsi five-jointed.

Gryllidæ. Jumping hind-legs. Cerci not jointed. Ovipositor of two pairs of processes, cylindrical. Tarsi three-jointed. No styles. Auditory organ on fore-leg.

It is very unfortunate that the Locusts should not form part of the family *Locustidæ*, and to avoid confusion Kirby uses another set of terms in which the *Acridiidæ* are called *Locustidæ*, the *Locustidæ* become the *Phasgonuridæ*, and the *Gryllidæ* the *Achetidæ*. It has been thought better, however, to adhere to the old names. It should be noted that a periodical Cicada is called a "Locust" in the United States.

Blattidæ.

Cockroaches, Blackbeetles. Roaches.

Broad, flat insects, with large pronotum completely shielding head, which is bent downwards. Coxæ large and free, covering ventral surface of thorax and base of abdomen.

The common cockroach, or so-called blackbeetle, so common in houses, is a typical member of the family Blattidæ, except that the female is practically wingless.

Cockroaches are moderately large insects, nearly always coloured in browns or blacks, but some tropical ones are vividly coloured in blacks, orange-yellows and greenish tints. One form has the antennæ banded in shades of white and red; a species from Brazil rolls itself up like a woodlouse, and yet another unusual form in Madagascar has projections on the sides of the thorax. They are very quick on their feet and

FIG. 11.—*Periplaneta americana* (about nat. size).

not easy to hold when caught. There are many more species in tropical than temperate regions, but certain species have been distributed all over the world on ships.

The chitinous covering is generally soft; the pronotum is like a shield covering the head, although in one species this does not occur. In some apterous forms the posterior angles of the pronotum extend backwards. The sternites of the thorax are rudimentary, possibly owing to the protection

fforded by the large coxæ. In some there is a small portion f the integument covered by a much thinner membrane, near he base of each coxa, which, it has been suggested, are extra ense organs. The thorax is articulated to the abdomen by ieans of six cervical sclerites. The abdomen itself is composed f ten segments, but all of them are not readily visible, and the egments vary according to age, sex, and species, the posterior egments being invaginated. The anal cerci spring from the enth segment. They are flat and segmented and vary in ize and length, and are absent in a few. They are reduced n the wingless forms. Near the anus are two plates, one on ach side, known as the Podical Plates, which Huxley con- idered might represent the tergites of an eleventh segment. Odoriferous glands are scattered over the dorsal surface of the bdomen, or may be concentrated on two or more segments, nd give rise to the peculiar odour associated with these insects.

The mouth-parts are of the normal biting or crushing type, ne mandibles being short, blunt and heavy. The palpi are ell developed, and the labium is fused medianly. The head bent down under the prothorax, but can be lifted up to some xtent, throwing the mouth-parts forward. The under surface f the head is composed largely of the huge submentum. There a large clypeus. Small areas of lighter colour are present ear the antennæ, known as the fenestræ. The eyes are large nd emarginate to allow for the insertion of the antennæ. In ne males of some species, ocelli replace the fenestræ. The ntennæ are very long and flexible, being composed of a large umber of similar joints up to a hundred in number.

The tegmina are very variable in form, very large in some, bsent entirely in others. The wings are also variable, being metimes absent, in others very large, as is the case in a acific genus in which they are larger than the tegmina. They re often very different in the sexes of the same species. The gs are long and fairly large with enormous coxæ and distinct ochanters. Many large spines adorn the tibiæ and femora, nd the tarsi are five-jointed, the fifth joint being long, with vo claws and often an arolium. In some cases the basal ur tarsal joints are padded on the lower surface. There are vo thoracic spiracles which are fairly large, and eight smaller nes situated on the abdomen. The sternite of the seventh

segment in the female has the posterior portion boat-shaped, to assist in discharging the egg-case, and it is larger than the others. This plate is known as the Lamina subgenitalis, and corresponds with the sternite of the ninth segment in the male. The Lamina supra-analis, or the tenth tergite, also differs somewhat in the two sexes. In addition to the cerci the male is provided with a pair of styles. Nymphs of both sexes, however, possess these styles, but they are lost by the female during one of the ecdyses. In some males the styles are not present, or one only may be missing, in which case it is represented by a notch. Males are smaller than females, and if there is a difference in the alar organs of the two sexes, it is the male which has them in the most complete form. The difference between the sexes is, on occasion, so great that they would appear at first sight to belong to two different species.

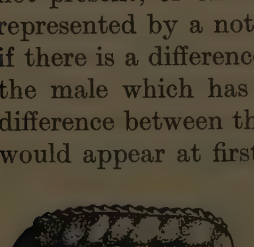


Fig. 12.—Cockroach Egg-case. (× 4.)

The internal organs have been the subject of much study, and are familiar to all students of zoology. There is a large crop and a small gizzard with tough walls, eight hepatic caeca and numerous fine Malpighian tubules. The salivary glands are large and furnished with receptacles. The tracheal system is well developed and there are three thoracic and six abdominal ganglia. The ovaries consist of eight egg tubes, each opening to a common oviduct, the latter joining with the corresponding one on the other side in a common uterus, which is surrounded by a diffuse colleterial gland. An organ which may be a spermatheca opens into the cloaca. The testes consist of thirty to forty vesicles situated on a tube which forms the vas deferens. A large mushroom-shaped gland opens into the vesiculae seminales. The testes are not active in the adult, their functional activity being lost after the last ecdysis, and the spermatazoa are stored in the vesiculae seminales until required. The conglobate gland of Miall and Denny opens on the exterior portion of the gonapophyses. Copulation takes place, but how the eggs are actually fertilized is not clear. The egg-case is formed in the uterus and completed long before it is deposited. In some it is retained within the female's body and

the young roaches are born alive. It can often be seen half out of the mother's body, and in this condition is sometimes carried around for some time.

Owing to the retiring nature of these insects little is known about their life-history. It is certain, however, that they are very long-lived for insects, and most probably take five years to reach maturity, having cast their skins about seven times in the process. *Periplaneta americana* is said to take four years to reach maturity, but on the other hand *Phyllodromia* is said to become adult in a few months. The case in which the eggs are laid varies in size and shape according to species, but is generally something like a miniature gladstone bag without handles. It contains about sixteen eggs which are cigar-shaped and arranged in a double row, the embryos being orientated so that they face one another. The case, when filled with eggs, is carried about by the female for some time before it is actually deposited. As already stated, some are viviparous, and in some cases the oothecum is wanting. The eggs do not hatch for some time, sometimes considerable periods elapsing before the nymphs emerge. When the eggs hatch the egg-case splits along the line of junction of the two ridges, owing to the expansion of the eggs in hatching, and possibly also on account of some softening fluid secreted by the embryos. The nymph is generally similar, but at times very different in appearance to the imago. It has fewer segments to the antennæ and cerci, and is paler in colour than the adult, and at first it is almost white, with black eyes. There are at least five, more probably seven moults, the wings completing their development at the last ecdysis, in which the terminal segment of the abdomen also becomes somewhat modified.

Both the nymph and imago are very quick moving, appearing to glide rather than run over the ground. Both are nocturnal and show great distaste for light. Most of the family are free living species in the open, a few have become domesticated, and a few are aquatic in the Eastern tropics. The males of the genus *Heterogamia* are remarkable, inasmuch that they have been recorded as coming to light. The household species are gregarious. All assiduously comb themselves with the spines on their legs and pass their antennæ through their mouth-parts to clean them. The food of cockroaches is not

restricted to any one article and may consist of any animal or vegetable matter, their own cast skins and egg-cases, or the dead bodies of their own species. All sorts of curious things such as blacking and emery paper have been recorded as having been eaten by them, but according to one authority "cucumbers disagreed with them horribly." None has been recorded as feeding on living plants. Human food is of course often spoilt by the fœtid smell which they leave behind them.

It is noticeable that only one species is found in one locality, two or more never seeming to fraternize. Cockroaches have also been known to migrate in a body from one house to another without any apparent reason. Hibernation if necessary may take place at any stage, but there usually is none. These insects are very sensitive indeed to cold, and extremes of climate will stop breeding at once. The outdoor species may be found among fallen leaves, under stones, in thick grass and other such concealed localities, whereas the domesticated species are found in cracks and under floors, preferably in such warm places as kitchens and bakehouses. They are preyed upon by birds, rats, spiders, and other such animals. Fossorial wasps enter houses in search of them and an Evaniid oviposits in the egg masses. Centipedes probably feed on them, and Nematodes form internal parasites. In the alimentary canal there is normally present a large fauna of micro-organisms such as protozoa, bacteria, and gregarines, and these seem to have no effect on the health of the insect.

The principal monographs are: Kirby's Catalogue (1904); Shelford, *Genera Insectorum* lv (1907), lxxiii (1908), lxxiv (1908), ci (1910), cix (1910); Miall and Denny (1886); Lucas (1920).

There are only three indigenous British species (*Ectobius*), which are free livers out of doors. The household species comprise five naturalized aliens of various and sometimes doubtful antecedents. There are over a thousand world-species known.

At present cockroaches are merely household pests, eating human food and spoiling much more by giving it an odour. The possibility of their carrying disease must, however, always be kept in mind, indeed it seems almost certain that they will be found to do so sooner or later. It has been recently stated that they carry cancer in rats and mice. Strict cleanliness is

a preventative to a certain extent. On the first appearance of cockroaches in a house, finely pulverized sodium fluoride, or, if that is not obtainable, borax, should be dusted all over the places they frequent. It is best to use a dust gun so that the poison can be blown into all cracks and crevices. Control should be kept up for several weeks as the eggs do not hatch for some time.

The family is divided for purposes of classification into twelve sub-families. The most noted members are :—

Blatta orientalis in which the male wings are short and entirely absent in the female. This is the commonest English household species.

Phyllodromia suppellectilium is winged in both sexes, and is the household species of the tropics.

Blatella germanica is common in houses in the Eastern United States of America, while

Periplaneta australasiæ is common in the Southern States, and is the species most usually found in ships.

Periplaneta americana is the largest of the series, and often flies by day. It is well distributed over the world in docks, warehouses, and such places, while there is a very flourishing colony in the reptile house at the Zoological Gardens, London. It was this species whose photograph appeared in a famous daily paper, together with a short note saying that if several of these "beetles" (*sic*) were placed under a blind man's nose he would say he was sniffing roses!

Mantidæ.

Praying mantises, Soothsayers.

Orthoptera with long prothorax and raptorial front legs.

The popular name for these insects has arisen from their characteristic attitude of supplication and the remarkable form of their front legs. The above characters are constant throughout the family, but the variety found in outline and general shape is very great. The colour is cryptic as a rule, but deceptive colouring is often present on the hind-wings, and

Harpax ocellata is said to be able to change its colour in accordance with its surroundings. Mimicry of plant structures is very well developed. *Amorphoscelis* mimics the bark of trees, many simulate foliage, some are stick-like and sway to and fro as if moved by the breeze, some live in grass and mimic grass stems, while *Eremiaphila*, and others which live where there is no vegetation, are very like the sand on which they walk. The young forms mimic other insects, such as ants, by means of a black outline on a green ground, and some look extremely like flowers, presumably to attract insects to them. None inhabits the cooler regions of the globe, the most northerly district where any species has been recorded being Havre,

FIG. 13.—*Hierodula westwoodi.*

France. They are fairly numerous all over the tropics and sub-tropics.

The prothorax is typically elongate, but may be shortened in some species. It may also be extended at the sides, giving a grotesque appearance. The abdomen is moderately long, formed of ten segments when viewed dorsally, and is provided with a pair of two-jointed cerci springing from beneath the sides of the tenth tergite. Like the thorax, the abdomen may be expanded or it may be leaf-like. The mouth-parts are of the usual carnivorous biting type and are hypognathous. The labium is completely fused. The head is free, rather elongate and very mobile, being attached to the prothorax by a slender

eck which is concealed by the pronotum. In some it is bent own so much that the mouth-parts are almost pointing back-ards. The eyes are very large and prominent, and there are ree ocelli forming a triangle, with the apex pointing down-ards. Some extraordinary shapes occur in some species, e eyes being horn-like and the ocelli being carried on pro-ctions.

The antennæ are filiform, but are pectinate in some males. hey vary greatly, may be short or long, and may differ cording to sex. The wings are generally present, apterous ecies being rare. The tegmina are narrow and often resemble aves. They are sometimes marked, more so in females than ales, and when at rest one overlaps the other. The hind-wings e very much larger than the tegmina and are much more licate. They are frequently brightly tinted or flame-coloured d close fanwise. The anterior portion is generally more bust. The anterior legs are inserted near the anterior por-on of the prosternum. The coxæ are long, the trochanters iangular. The femora are elongate and furnished with sharp ikes and teeth on the lower surfaces. The tibiæ are shorter, d are articulated with the femora so that they can be snapped like a clasp-knife. The lower surface of the tibiæ is provided ith teeth, which fit into those on the femora when the two gments are closed together. The middle-legs are inserted the posterior portion of the mesosternum. The coxæ of all e legs are large and free, the tarsi are five-jointed, and no lvillus is present. The middle- and hind-legs are of the dinary walking type, specially suited to the poising attitude quired by their habits, but in some the hind-femora are ickened, and the insect is capable of leaping to a limited tent. Femoral brushes for cleaning the eyes or antennæ ve been described. Viewed ventrally there are eight dominal segments in the male and six in the female. In e genus the male has the tegmina and wings normal, while e female has them undeveloped.

The salivary glands are large and are provided with recep-cles. There are eight hepatic cæca, and about a hundred alpighian tubules. Schindler has stated that the latter are serted on the mesenteron itself. The ovaries are formed of ty egg-tubes, which are joined together in clusters of six

with a common opening. The clusters are placed at intervals along two tubes which join to form the oviduct. There are a large number of sebific glands of two distinct kinds. The testes are complex. Eggs are deposited in a large oothecum which is peculiar to Mantids. The female places the tip of her abdomen against a twig or grass stem and exudes some foamy matter which is the secretion of the sebific glands frothed by the action of the gonapophyses as it comes out. This soon hardens and forms the base of the oothecum. The eggs are then laid in groups, a proportionate amount of frothy matter being exuded at the same time, until the whole oothecum is built up, group by group. It is shaped by the end of the abdomen, and possibly in some cases by the help of the tips of the tegmina. In each egg-chamber the eggs are arranged symmetrically, and the chamber communicates with the exterior by a passage, which forms the means of egress of the newly hatched nymphs. A delicate membrane closes the exit passages until pushed aside by the emerging young.

The nymphs hatch in groups, and on reaching the exterior of the oothecum drop down and remain suspended in the air by means of two silken threads, which are produced by two papillæ on the ventral surface of the tenth sternite. They remain thus suspended until after the first ecdysis, after which they live a free life. The first skin is a true larval skin, and does not entirely envelop the young Mantid like a cocoon, the legs and antennæ being free. On the abdomen are situated a series of spines pointing backwards, which enabled the young nymphs to emerge from the egg. On emergence the young nymphs have the appearance of small pupæ, but after the first moult they resemble the adult. The number of antennal joints increases with age, and the ocelli appear with the wing rudiments. There are seven moults.

The adult Mantid has an extremely innocent and even intelligent air, which is far different to its ferocious habits. It holds itself in a semi-erect position with the fore-legs in an attitude of prayer, and when it moves does so by means of its middle- and hind-legs, the fore-legs having little power of supporting it. The Mantid has a habit of staring, and is one of the very few insects which can be more or less tamed. It is the only insect which appears to see man as an individual. Some

ome to light. Both adults and nymphs are very rapacious eders, and are entirely carnivorous, feeding on all kinds of sects. None is recorded as feeding on vegetable food, and ne order may be included with those insects known as general redators. It is stated that some of the larger species will tack and devour small vertebrates. The female generally evours the male after copulation, and the nymphs often eat

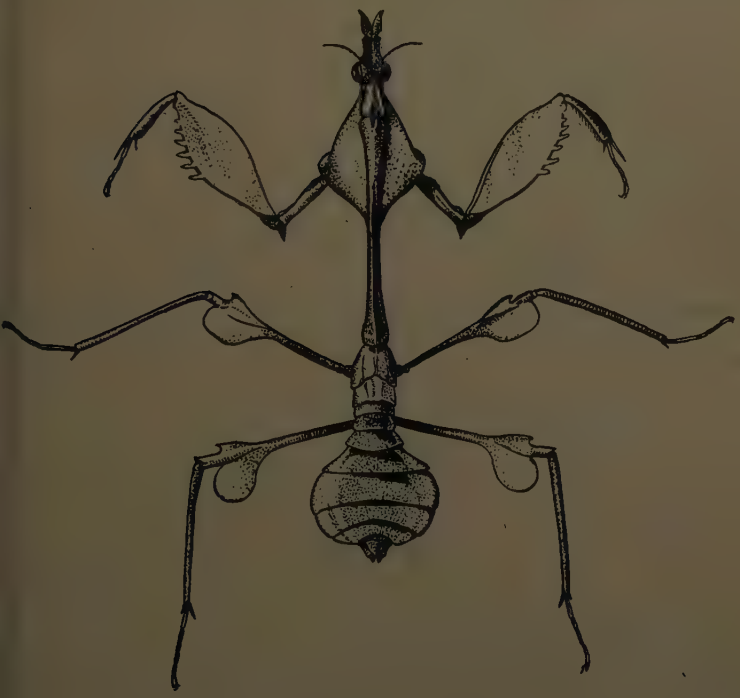


Fig. 14.—*Gongylus gongyloides.*

e another. In the Zoo, two Mantids cannot be kept together. biret records a male which was decapitated by the female nen he approached, but which nevertheless succeeded in pulating. Next day, however, the female devoured the capitated body of her spouse. The Mantid will either sit rfectly still and wait for an insect to come within reach, or ll carefully stalk its prey. When within reach it is caught the fore-legs and carried to the captor's mouth. The head

of the victim is usually taken off first, and its body then gradually torn in pieces. Portions only are eaten, the rest being thrown away. Some species which live in deserts are said to be located in regions where no other insect life exists. If this is so, what do they feed on ?

Hibernation, when it takes place, is in the egg stage. Thus *Mantis religiosa* in the South of France lays eggs in September which do not hatch until the following June. In the tropics, however, hibernation may not take place, and the eggs hatch in as short a time as twenty-four days. One brood yearly with hibernation as an egg is probably the rule in tropical species. Where they abound Mantids can be found on bushes, on the bark of trees, in grass, and other places where there is a profusion of insect life. A large proportion of the egg-masses are parasitized by Chalcids provided with a long ovipositor in order to reach the eggs within the oothecum. Checks on adults and nymphs include birds, monkeys, and other insectivorous vertebrates. Much attention has been paid to the habits of the Mantids, but comparatively little to the anatomy.

Among a large number, the following authorities may be consulted: Woodmason (1889), Kirby's Catalogue (1904), Giglio Tos, *Gen. Ins.* Fasc. 144 (1913), 175 (1921), Williams and Buxton (1916), Giglio Tos (1916, 1917, 1919), Rehn, *Gen. Ins.* Fasc. 119 (1911).

There are some six hundred known species, all inhabiting warm climates. Attempts have been made in the United States to establish them as general beneficial insects, but it has been found impossible to acclimatize them to anything approaching a hard winter. Thus none can be kept going north of Ontario, and some colonies placed in New England have died out. In suitable climates they help in keeping down the insect population, but they do not restrict themselves to any one type of insect. They form part of that very valuable section of insectivorous animals which feed on any insect that becomes abundant: like the birds, they eat whatever insect is available; and this is a most useful group in checking the periodical wave-increase of insects, which are only pests when in great abundance.

Phasmidæ.

Stick and leaf Insects.

Head protruded, prothorax short, mesothorax long, legs imilar to one another.

Phasmids are large and vary greatly in form. The colour generally cryptic, but deceptive colouring is achieved in many y brilliantly coloured hind-wings. All mimic some form of af or stem structure, and some simulate mosses and lichens. n the stick insects the whole body is elongated and resembles twig, the insect even swaying from side to side as if moved y the wind. The leaf insects are most highly developed in

Fig. 15.—Stick insect ♀ (*Carausias morosus*) (nat. size).

e genus *Phyllium*, but it is the tegmina which assume the incipal rôle in the mimicry in this family. Mimicry of plant ructures is brought to the highest perfection known. They e restricted to and universal in warm climates, having an tolerance for cold. *Bacillus gallicus*, however, exists as far rth as Central France, and *Carausias morosus* has been bred England in captivity for the last ten years. The largest mber of species is found in Australia, and the family seems have a particular preference for islands.

The prothorax is always small. The mesothorax may be nall in a few, but is generally long, in some cases being six nes the length of the prothorax; the legs and wings, if present,

being attached to the posterior end. The abdomen is generally elongate and formed of ten segments. The cerci are flattened and segmented. In some species there are glands on the thorax capable of emitting an acrid and foul-smelling fluid. The head is free, the mouth-parts of the ordinary mandibulate type, and the eyes prominent. Ocelli are variable and are said to be present and absent in different individuals of the same sex and species. The antennæ are long, simple, and formed of anything from eight to a hundred segments. The tegmina are generally small or absent, even when the hind-wings are well developed. The hind-wings in the latter case are folded fanwise and lie along the back, looking like tegmina. Taking the family as a whole the rule is that the tegmina are atrophied. The legs are simple, the fore pair often being stretched forward, the femora concealing the head. They are often flattened and leaf-like, and the fore-legs are frequently longer than the rest. Throughout the family they vary to some considerable extent. The coxa and trochanter is small, the tarsi are five-jointed, and there is an arolium between the claws. The female is generally the larger and has the eighth abdominal segment modified on its ventral surface to form a gutter to assist in depositing the eggs. The two segments following the eighth are concealed by it. If there is a difference in the alar organs it is the male which has them most highly developed. Plant mimicry is highest in the females. In *Phyllium* the male has not got the leaf-like tegmina which produce the great leaf resemblance in the female, and in the latter the wings are reduced to minute processes. The males are more mobile, and have claspers at the end of the abdomen.

Little is known of the internal structure. In *Phyllium* there are no salivary glands, and no hepatic caeca. The Malpighian tubules are long and very numerous, and there is no distinction between the crop and gizzard. There are three thoracic and five abdominal ganglia. The tracheæ are well developed, but have no air vesicles. The ovary is formed of from eighteen to twenty egg-tubes. Comparatively few eggs are laid, about thirty, but the number may go up to a hundred. They are discharged at random and fall to the ground, producing a noise like the patter of rain on the leaves of forests where these insects abound. Each egg is really a capsule containing an

gg. The capsule is beautifully sculptured in many cases and s provided with a lid which is pushed off at the time of hatching. The general evidence tends to show that the capsule is elaborated in the egg-tube. Only one is laid at a time.

When ready for emergence the meso- and meta-thorax of the young nymph are not very long, but by the time it has fairly emerged they have enlarged to their proper proportions. The body expands so much on hatching that it would appear almost impossible for the newly hatched nymph to have come from

Fig. 16.—*Phylllium scythe.*

he egg beside it. In *Phyllium* there are three ecdyses, a rowth similar to that on hatching occurring after each one. At the third moult the insect suddenly shoots out to its full ize. Growth occupies from six weeks to twelve months. Wings ppear in *Phyllium* after the second moult. In the apterous orms the differences between nymph and adult are very slight. The nymph and adult are both very sensitive to cold. The atter has the power of reproducing lost limbs, and there is a uture between the trochanter and femur which enables a leg

to be thrown off easily. It is said that in *Phyllium* one individual will nibble the edge of the tegmen of another apparently in the belief that it is a real leaf. A Brazilian species of the genus *Prisopus* is aquatic, living in mountain streams under stones. The under side of this species is densely pubescent. Males are exceedingly rare in some, and reproduction in these cases is parthenogenetic.

All are herbivorous and eat large quantities of food. They are characteristic chiefly of tropical forest areas, where they live in the tops of trees, their eggs falling like rain and sounding like a shower (Bates). Hibernation takes place when necessary as an egg, which is laid in autumn and hatches in the following spring. Great numbers of eggs are parasitized by Ichneumonids, and birds, monkeys, and Reduviids attack the nymphs and adults.

The chief works on *Phasmidæ* are : Kirby's Catalogue (1904), Brunner von Wattenwyl and Redtenbacher (1906, 1908), Meissner (1916).

About six hundred species are known, of which four or five are native to the South of Europe. They are essentially forest insects, and when abundant may strip acres of trees. In some cases they may prove a source of danger to cultivated tree crops, and when accessible trees may be sprayed with a stomach poison. *Lopophus coccophagus* destroys palm trees in Fiji and other Pacific islands.

Acridiidæ (*Locustidæ*).

Grasshoppers, Locusts, Shorthorn grasshoppers.

Medium-sized to large insects with short antennæ, never extending beyond the prothorax ; jumping hind-legs ; an auditory organ situated on the abdomen.

The Acridiids form the most important group of the *Orthoptera* and contain the true locusts, which have been known as first-class pests from the time when man first started to grow crops. It is unfortunate that the true locusts do not form part of the family *Locustidæ*, and attempts have been made to remedy this confusion of names by altering the nomenclature

of the Saltatoria. Thus Kirby styles the *Acridiidæ* the *Locustidæ*, while reserving the name *Phasgonuridæ* for the true *Locustidæ*. Confusion may to some extent be avoided by naming the *Acridiidæ* Shorthorn grasshoppers as distinct from the Longhorn grasshoppers or *Locustidæ*.

Acridiids are compressed laterally, and have a large head with prominent eyes. The wings are pressed to the sides, and the femora are large and point upwards and backwards. The general shape is uniform throughout the family, but can be adapted for special purposes, such as is the case in *Chrotogonus* which is flattened for living on the surface soil. Colour varies greatly in the same species, there being in some two distinct colour schemes in one life history, cryptic in the young and deceptive in the adult. Although the colouring in the family follows generally the cryptic or deceptive schemes, many instances are met with in which the colours are of a brilliant warning type, combined with the emission of a frothy secretion from prothoracic glands and a peculiar sound-producing organ (*Aularches*); these forms are probably extremely well protected against enemies. Many change colour at definite times, such as the Bombay locust—*Acridium succinctum*, which is brown with yellow stripes. On its first migration the body and head are suffused with red which persists during the swarming period, changing to a deep brown or black with yellow streaks at the coupling season.

A few depart widely from the standard type. Thus *Proscopides* resembles a Phasmid more than an Acridiid, and is generally apterous. The family is more adapted to warm climates than cold, but is more sub-tropical than tropical. Locust damage occurs almost entirely in warm climates, but swarms have been recorded in England.

The body is large and flattened from side to side. The prothorax is large and arched, and is often elongated to form a hood covering the base of the wings, or is furnished with projections at the sides. The prosternum often has a process projecting between the front legs. The thorax as a whole is well developed and clearly segmented. The abdomen is composed of ten segments. The mouth-parts are large and hypognathous, with a well-developed labrum and mandibles with large cutting teeth. The maxillæ and labium are also

well developed, while the hypopharynx forms a blunt tongue lying on the floor of the mouth. The head is sunk in the thorax and carries large eyes widely separated. There are three ocelli which are universally present, though very small in some. The antennæ are composed of thirty segments at most, are generally curved back over the thorax, and are flattened in some.

The tegmina and wings function together as one pair of organs in flight. The former are long and narrow and of a fine parchment-like texture. They usually project beyond the abdomen, but are sometimes shorter, and in the *Tetriginæ* are reduced to short lobes covered by the prolongation of the pronotum. The wings are large and much more delicate in

Fig. 17.—*Tryxalis turrita.*

texture. They are folded fanwise and covered by the tegmina when at rest, are many-veined and often coloured at the base. In some species they are short or reduced. The legs are placed on the sides of the thorax, not ventrally. The two anterior pairs are similar and smaller than the hind-legs, with small coxæ. The tarsi are three-jointed, with three pads on the under surface of the basal joint, which gives the appearance of a five-jointed tarsus when viewed from below. The hind-legs are distinctive of the Saltatoria and are used for jumping. The femur is thickened, more at the base than at the apex. The tibia is long with two rows of spines on the posterior edge, and is capable of being bent under the femur. There are two thoracic and eight abdominal spiracles.

The female is provided with digging organs, which are formed by four valves projecting beyond the supra-anal plate and sub-genital lamina. The upper pair arise as outgrowths from the ventral portion of the ninth abdominal segment, the lower pair

rom the eighth. It is the upper and more strongly chitinized air which is used in excavating the hole for egg-laying. The nus is placed above the genital aperture. The abdomen ontracts and extends to a great extent, being retracted during opulation and extended during oviposition. The male has he subgenital lamina curved and pointed, forming the apex f the abdomen. The two sexes often differ in size and colour.

The alimentary canal is straight and contains no gizzard, he crop being constructed to form a substitute for it. The alivary glands are small; there are three hepatic caeca and umerous Malpighian tubules. Three thoracic and five bdominal ganglia are present.

The sense of hearing is particularly well developed in this amily, no doubt coupled with their facilities for sound pro-

Fig. 18.—*Acridium melanocorne.*

uction. This is effected by rubbing the inner surface of the emur against the surface of the tegmen, a series of beaded rojections on the femur grating over a raised vein on the egmen. This arrangement is limited to males, but females ave rudimentary sound organs. The auditory organs are, owever, found in both sexes, on the base of the abdomen, elow the tegmina and wings, and exist in the great majority f species. Those species in which there is no auditory appara- us are also wingless and without means of producing sound, ut there are exceptions to this. The exact function of the uditory organs is not known. Other organs for the perception f sound are probably present, and the organs peculiar to cridiids may be limited for this reception of only one kind f vibration. On the other hand those species generally upposed to be without means of sound production may make ome sound which is inaudible to man. In the sound-producing

species the "song" is very uniform in character. Some make a noise during flight, which apparently comes from the friction of the wings. The sound-perceiving organs peculiar to the family are situate one on each side of the dorsal aspect of the first abdominal segment, above the articulation of the hind-leg. Three forms can be distinguished; a membrane surrounded by a rim, a membrane slightly depressed with a portion of the segment projecting over it, and a marked depression with the segment projecting over it, giving it the appearance of a cavity opening to the exterior by a slit.

The membrane or tympanum is supplied with a nerve ganglion, muscles, and a complex tracheal apparatus.

The tracheæ are well developed and provided with numerous air sacs which can be dilated preparatory to flight, a condition which is well marked in the migratory locusts just before and during the long flights.

The testes are united in a single envelope. The egg-tubes are likewise united, their terminal threads converging to form a composite ovary, and opening into a calyx which is prolonged at its extremity to form a long convoluted tube. In locusts it is important to watch the development of the ovaries in order to forecast the time when egg-laying will take place. In the case of the Bombay Locust (*Acridium succinctum*) it has been observed that the reproductive organs do not become fully developed until directly before coupling. Before that they are very small, the tracheæ being still dilated and the fat body small. Coupling takes place in this case for two days, at the end of which the male dies. Five days after the female starts to lay eggs. In laying eggs the female excavates a hole in the ground by means of the gonapophyses, and deposits the egg mass, afterwards leaving little trace of the operation. The eggs are deposited with fluid, which hardens to form the egg mass, which is one or two inches long, nearly cylindrical in shape, and straight or curved according to the nature of the ground. In gravelly soil the mass may be twisted. About fifty to a hundred and twenty eggs are present in each egg mass. Several observers have described the methods of egg-laying. Coleman and Kannan have described the oviposition of the Rice grasshopper (*Hieroglyphus banian*), which lays its eggs in the embankments surrounding paddy

elds. The four horny valves are pushed into the soil and nen opened, pushing the soil outwards. They work in one lane only, so that to make the excavation round the body is otated—it is capable of a rotation of 180°. As soon as a proper epth has been reached the lower end of the hole is enlarged nd the walls made smooth, which is done with great care. A uid is then expelled accompanied by convulsive movements f the abdomen, and is worked up into a froth by the move- nents of the horny valves. When a small amount of froth as been formed the posterior pair of valves separate from the nterior pair, and the tip of an egg appears in the space between hem. The posterior valves are then brought forward and lasp the egg, which is then forced into the froth at the bottom f the excavation. Then more froth is made and another egg roduced and so on. The eggs are arranged in a certain degree f order, but it is not by any means regular. Digging the hole ccupied this species for thirty minutes, the formation of the gg chamber took from fifteen to twenty minutes, and the eggs ere deposited in another thirty minutes, making a total of an our and twenty minutes. By killing the female while in the ct of ovipositing, it was found that the left ovary was first mptied of eggs, which did not come alternately from each vary as had formerly been supposed.

The eggs are elliptical, and longer than broad. They are ranged in the egg mass so that the head of the embryo is at he upper and the micropyle at the lower end. On emerging, he nymph ruptures the egg-shell, according to Riley, by means f the spines on the apex of the tibia, and then moults a mem- rane which he considered to be part of the embryonic mem- ranes (*Caloptenus spretus*). In the case of the Rice grasshopper he authors quoted above state that the chorion is ruptured y the convulsive movements of the young nymph, together ith a swelling out of the body just behind the head. It is en still enclosed in the amnion, and makes its way thus to e surface of the soil through one or two inches of earth. As on as the surface is reached the amnion is cast by means of a lit just behind the head.

The young hopper has the general form of the adult, but th fewer joints to the antennæ, and the wings and internal nital organs absent. It is not easy to distinguish the species

in the early stages, and colour changes occur in the nymph and to some extent after full development is reached. Wings appear after the second or third moult, of which there are five to seven, the males probably having one less than the females. The cervical bladder between the head and prothorax used in hatching is again used at each moult, the pressure from it bursting the dorsal cuticle. In the Bombay Locust three distinct periods of development may be noted. Firstly the change to the adult condition signalized by the full development of the wings; secondly, conspicuous colour changes; and thirdly, the sudden development of the genital organs after the last migration.

The food consists mostly of vegetable matter, lichens, mosses and low forms of plant life being consumed by some, while others are limited to a single food-plant. More generally, however, there is a range of several food plants, the range being greatest in the locusts. Cannibalism is found in certain genera such as *Schistocerca* when there is a shortage of vegetable food or when a nymph or adult is sickly. Refuse, string, and other substances are also eaten by some. *Tettix* and allied genera are aquatic, with expanded hind tarsi for swimming.

Hibernation takes place in the egg stage, but a few hibernate as adults. As a whole there seem to be no regular seasons for reproduction, but most are fairly regular, the most important factor being climate. Many are only one-brooded, others have two, and some have several broods during the year. The natural habitat is the plains, cultivated crops and forests.

In view of the enormous importance of locust swarms the natural enemies of Acridiids have been widely studied, and many attempts made to propagate diseases and other checks among the swarms. The egg masses are eaten by a large number of insects, among which *Meloidæ* are important. These beetles deposit between four and five hundred eggs, which hatch in about ten days. Each larva will thus destroy from one to several egg masses. Certain Ichneumonids, Chalcid, Bombiliids, and Anthomyids, act as checks of lesser importance, while some Sarcophagids are distinctly useful. Tachinids prey on nymphs and adults, and a mite is said to be destructive to the hoppers and eggs in North America. Enchytræid and Gordiid worms are found in considerable

ımbers attacking locusts, while birds and mammals do nsiderable execution. Monkeys, marmosets, squirrels, mon-oses, and similar animals, greedily devour grasshoppers, as many birds. Certain fungous diseases attack them, and me attempt has been made to use these as an artificial control, ıt although effective work has been done in Colorado, the sults of similar trials in Texas were negative.

Of bacterial diseases the locust epizoötic caused by *Bacillus ridiorum* d'Herelle has had some success as a control. The sease is spread naturally by the liquid excreta of diseased usts falling on leaves which are eaten by other members of e swarm, and also by cannibalism and the infection of the gs during oviposition by a diseased female. Susceptibility the disease varies with the period of the life-history, it being eatest in the adult at the time of egg-laying, and least in the ung nymphs. In the nymphal stage it is greatest about the ne of the last moult. This period appears to be the best for tificial propagation, as the nymphs are then crowded together d have large appetites, whereas in the adult stage propagation the disease would not be so easy. The virulence of the cillus decreases greatly in culture, and to bring it up to the quired strength at least twelve successive passages through ults or nymphs must be made. A weak culture renders the usts immune to a certain extent. The culture is injected to the body cavity of a locust, and when it is nearly dead the uid excreta is squeezed out and injected into another in-vidual and so on. The virulence is great enough when death curs eight hours after injection. This process takes five or days. When the required virulence has been attained the ecific bacillus is isolated by means of an agar plate and ltivated for twenty-four to thirty-six hours, when it may be ced directly in broth containing dextrose. This is then rayed on the vegetation. Considerable success has been tained by the use of the bacillus in the Argentine Republic, tably in 1912, but elsewhere results have not been so satis-tory. At best the method is only a subsidiary one to other ntrol measures, but provided the technique necessary to duce the epizoötic is efficiently carried out it should be a luable aid against locust swarms. The cultures can be tained from the Pasteur Institute.

In addition to organized checks, the weather has an important action in controlling locusts. Dry weather kills a large number of egg masses when they are new, and is also fatal to hoppers. The adults do not seem to couple until rain has fallen, and a heavy fall will delay the action of the bacterial disease for some time.

Reference may be made to Kirby's Catalogue and Lucas' *British Orthoptera*, as well as the following: Morse (1904), Lefroy (1905), Coleman and Kannan, Dept. Agri. Mysore, Ento. Ser. *Bull.* i; Riley, U.S. Dept. Agri. Div. Ento. *Bull.* 25; Walton, U.S. Dept. Agri. *Farmer's Bull.* 747; Marshall, *Microbiology* (Churchill); *Gen Ins.* Burr, Fasc. 15 (1903); Hancock, Fasc. 48 (1906), and Bolivar, Fasc. 90 (1909).

There are some two thousand species known, of which only eleven are British.

From an economic point of view the Acridiidæ are divisible into two distinct classes, those which have recurrent migratory habits and those which do not. To the former class belong all the locusts proper, which behave as ordinary grasshoppers until from various causes they migrate in huge swarms, when they become locusts. This habit is confined to certain species which are well known. Certain species of migratory locusts, however, regularly inhabit countries without forming swarms, such as *Pachytylus cinerascens*, which is to be found in Belgium, and individuals of migratory species are seen in Scotland. Many isolated specimens of locusts found in countries where they do not form swarms are probably imported in ships. Locust plagues appear suddenly and clear away all vegetation in a few hours, resulting in famine and often in pestilences owing to the numbers of dead insects left behind. They disappear as suddenly as they arrive. Although large quantities of eggs may be deposited, the resulting progeny may entirely disappear after a few seasons. Swarms arrive in certain districts at intervals of a number of years, the rapid increase of numbers in their native haunts which leads to the swarms moving off in search of food being ascribed to a number of causes. Among these may be mentioned a decrease in the number of parasites which keep them normally in check, the hatching of vast numbers of eggs which have not hatched previously owing to unfavourable conditions, and the fact that

large number of superfluous individuals seems to be necessary r the migratory instinct to be resuscitated. Years after the st migration to a particular spot it is believed that the swarms ke the same path as their predecessors. It has been tablished that after a migration, when the hoppers proceeding om the egg masses reach the adult state, they return to the nd of their ancestors. In the case of the "Voetganger," of outh Africa, the migratory instinct is developed before the ymphs have wings, and they travel long distances at this age, feeding as they go. The actual direction of the flight f a swarm is largely dependent on the direction of the wind, nd the air sacs being inflated, the locusts travel on the wind ore than by actual flying. Most of the flights of long distance ay be done by night, and they often travel great distances cross the sea. It is thus possible that the Biblical locust, *chistocerca peregrina*, may have come originally from South merica.

Details of the life-histories of locusts vary with the particular ecies. In the case of the Rocky Mountain Locust, *Melan-plus spretus*, there is a permanent region or native breeding round where it is always found in fair numbers. In a so-alled sub-permanent region it may propagate for several years, ut will disappear at times. A third region is temporarily isited in which the greatest damage is done, and from which he locust disappears in a year. Swarms fly on an average venty miles a day, but with a good wind will do up to three undred. Egg-laying takes place in the infested areas at the te of about three egg masses in six to eight weeks. The oppers on hatching remain where they are until after the econd or third moult, when they move along in masses, eating p all the vegetation in their path. When adult they swarm gain and go back to the permanent region.

The Bombay Locust migrates mainly at night, and is present large numbers in the breeding locality, the young hoppers enerally being hardly noticed until the wings appear. There re six periods in the history of the swarm, the first one being he emergence of large numbers on the breeding ground in eptember. In late October migration starts, and swarms egin to move in definite directions, to settle during the winter onths in forests. A second migration then takes place in

March until the end of May, when they begin to scatter and lose the migratory instinct. After the rains in early June have begun egg-laying takes place, and the hoppers hatch out in five or six weeks and take six weeks to reach the adult stage. In the control of locust plagues the first and most important aim is to have accurate and early information as to the size and locality of swarms and of the direction they are taking. This is provided for by the locust laws drafted by countries where plagues are regular, which insist on compulsory notification of swarm movements. The second most important point is to have some sort of co-operation between cultivators, so that control measures can be instituted over large areas simultaneously. This is also to some extent provided for in the locust laws, but must be supplemented by education and publicity.

By having accurate information of the origin of a swarm leading to the discovery of the permanent breeding ground, if there is one, much can be done in the way of permanently arresting the plagues. Action on the breeding ground has largely put an end to the Rocky Mountain locust as a plague, and the extension of agriculture to the foothills of the Rockies and to former deserts has eliminated many old breeding grounds. Having obtained information of the swarms and their line of flight, control resolves itself largely into those methods which appear best and most easily carried out on the spot. Thus it is possible in some cases to mark down swarms at night in cool weather and spray them with any handy insecticide while they are torpid, or, while in the same state, in the early morning they may be driven along into previously dug trenches and buried. Spraying vegetation in the line of their path has met with success, but care must be taken in the use of arsenical or other poisonous sprays where cattle abound, and the wholesale distribution of poisonous substances among native populations is not always desirable. Various poisoned baits have been used with success, consisting of bran, arsenic and molasses and the Criddle mixture in which fresh horse-dung replaces the bran is useful in that birds and cattle are less likely to touch it. Poisoned baits are a great success in protecting fruit trees. Deep ploughing at the right season of the year to expose egg masses to the action of the sun is useful, as also is discing. Where

rcumstances permit a reward may be made for the collection egg masses. The hoppers can be collected in great numbers the use of bags on suitable frames which are skimmed over e surface of the ground. The "hopper-dozer" as used in e United States is a more elaborate contrivance of the same nd, which is horse-drawn, and in which the hoppers jump into allow pans filled with water covered with crude petroleum, rosene, or other suitable liquid. The best form of "hopper-zer" is one which is pushed by the horse instead of drawn. ntrol by means of the locust epizoötic has already been entioned.

The disposal of large quantities of locusts needs some atten-n in formulating a locust campaign, and some attempts have en made to convert them to some useful purpose. An alysis of locust bodies made by the Transvaal Department Agriculture showed the presence of :—

	Per cent.
Protein	59·60
Ether extract	11·19
Crude "fibre"	11·26
Ash	5·12
Moisture	9·05

custs should thus form a source of food, and indeed *Pachy-us cinerascens* is fried in butter and eaten by the inhabitants Palestine, while locusts are freely eaten in India, and form ingredient of curry powder. It is as a source of cattle food, wever, that they should be considered, but for this they uld have to be killed by immersion in hot water. Only a all percentage of the swarm could be used in this way, and digestibility of the food would first need investigation. It been suggested that locusts would form a useful poultry d. As a manure they would no doubt be successful, but no ails are at hand of the availability of the crude "fibre," l the large proportion of fat might be deleterious. Pre-nably the 59·6 per cent. of "Protein" is based on a Kjeldahl lysis, which would include chitin.

rasshoppers are not of the same importance economically locusts, but locally often cause great damage. Large reases in numbers occur owing to cessation of parasite

activities and other causes. The methods of bagging and poisoned baits used against locust hoppers may be used effectively, and cultural methods can be applied according to the circumstances. The fungus *Sporotrichum globuliferum* which is used against Chinch Bug is said to be effective on some species.

The important economic genera are *Pachytylus*, *Aularches*, *Hieroglyphus*, *Acridium*, *Schistocerca*, *Melanoplus*.

Locustidæ (*Phasgonuridæ*, *Tettigoniidæ*).

Green grasshoppers, Longhorn grasshoppers.

Antennæ longer than head and prothorax; tarsi four-jointed; auditory organ, when present, on fore tibia just below knee. Musical organ, when present, on basal portion of tegmina. Ovipositor generally long and blade-shaped.

The Locustidæ form a group of little-known insects which are clearly not closely related.

As a body, they are much more fragile than Acridiids in structure, and are not given to taking long flights. No species is known to exhibit any tendency to migratory habits, and there is rarely any sudden increase in numbers, which is such a feature of the Acridiids. Nearly all members of the family are large, but as a whole they are sedentary and nocturnal. They have a habit of licking the front tarsi and repeatedly passing the antennæ through the maxillæ. Many are much modified in structure, such as *Schizodactylus monstruosus* in the East Indies, which has long tegmina and wings which are curled up at their extremities, is without ocelli, and is said to have no auditory apparatus. The predominant colour is cryptic in character, the most common shade being green. Burrowing and ground or nocturnal forms are coloured in sombre shades of brown and grey. Deceptive colouring of the hind-wings is common. Mimicry of plants, tree-bark, dead leaves, and insects is a feature of this family.

The tegmina often resemble leaves very closely, and in the South American *Pterochroza* they simulate leaves in varying stages of growth and decay, even the spots caused by fungous growths not being forgotten. In a specimen described by

runner von Wattenwyl, the marks made by leaf miners were eproduced. A few species bear some resemblance to stick nsects, and some nymphs mimic ants. The family is a tropical ne, few species being found in any country where the average emperature is low or where cold nights are the rule.

The mouth-parts are of the ordinary biting type, but in nany the mandibles and maxillæ are elongated owing to the arnivorous habits of the species. The prothorax is large, and n *Eugaster guyoni* in Algeria the mesosternum has two pores nder the anterior coxæ from which jets of a caustic fluid can e ejected. The ocelli are much more imperfect than in the cridiids, being often rudimentary, or sometimes entirely

Fig. 19.—*Sanna imperialis* (slightly over nat. size).

bsent. In some cases only one ocellus is present. The antennæ re long and slender, composed of more than thirty segments. The tegmina are usually large, and the wings even more so, ut in many species both are absent in the two sexes. The gs are very motile, especially the fore-legs of those species aving the auditory organs present. It would appear that he direction of a sound can be determined by these means. he abdomen is large and fleshy, the tenth segment being ivided into two parts, giving the appearance of eleven segents. A pair of cerci is attached which persists through fe. The ovipositor, which is represented at birth by two nall papillæ, is often of great length, sometimes longer than he body. It is formed by a pair of gonapophyses from the

eighth segment which form the lower portion, and by two pairs from the ninth segment, one inside the other. All the valves are held together by a system of tongues and grooves which allow a sliding motion to take place. Males are provided with external clasping organs.

The alimentary system varies with the life habit, two hepatic caeca being generally present. The tracheæ have no air vesicles attached to them. The auditory organ consists of a complicated series of otoliths in a cavity of the fore tibia. Air gains admittance to the organ by means of an orifice on the prothorax over the base of the fore-leg. This communicates with the one on the other side, and with the cavities near the tympana by means of vessels extending down the legs. These air channels are not connected to the main tracheal system. The tympanal organs are not present in all species. The musical organs are mostly confined to the males of the species, but are often present in both sexes. Sound is produced by a jerky movement of the tegmina which rubs a series of serrations on the inner surface of the left tegmen against a raised vein on the inner margin of the right. The motion is a rapid one, and the modifications of the tegmina are confined to the basal portions, so that when the wings are reduced the singing apparatus may still be present. The quality and volume of sound produced varies greatly within the family. The Katydids of the United States are notorious for their sound capacities. They belong to more than one genus, but are so called from the words "Katy did! she did! she did!" being recognizable. Among the Katydids sound production on the large scale is limited to the males, and is answered by a simple chirp on the part of the female.

The life-history has been worked out in very few species. The eggs are generally flattened and ovoid in form, and are laid in the earth, on the bark and twigs of trees, or on the stems of plants and grasses, either singly or in neat rows. Some are inserted in the edges of leaves. Those of *Meconema* are deposited in Cynipid galls, while *Xiphidium ensiferum* lays eggs in the galls of a Cecidomyid on willows. They are generally laid in the autumn and hatch late during the following spring, or in summer. Oviposition has been observed in the case of some Katydids. The tip of the ovipositor is first lubricated

by the mouth, an action which is repeated before the deposition of each egg. As the ovipositor is forced in between the leaf surfaces, on the edge of the leaf, two pairs of blades move backwards and forwards alternately, together with a slight rotary movement. It is worked in for almost its entire length, which forms a pocket for the egg, and is then withdrawn for half its length and the egg deposited. Before hatching the egg swells, and the nymph undergoes a moult during emergence. The young nymphs begin jumping and eating within a few minutes of emergence. The cast skin is generally consumed. Development takes place in five or six instars lasting about ten weeks, and is similar to that of Acridiids, except that the

FIG. 20.—Katydid (*Microcentrum retinerve* ♂).
(After Riley—somewhat simplified.)

wing pads appear much earlier. In the case of certain Katydids the egg is light grey, smooth and uniform. Hatching may occur in leaves which have fallen to the ground and are partially dried.

The young nymph is pale flesh-coloured on emergence, but soon changes to green. There are six moults, the wing pads appear at the second instar and can be distinguished at the fourth. The nymphal stage lasts from fifty-eight to eighty-eight days. The adults live in the shady parts of the orange trees during the day, and mating takes place twenty days after the last moult. After the last moult the tegmina and wings are generally colourless, but attain their correct shade within one hour. The food of Locustids is very varied. They may be herbivorous or carnivorous, or both. Possibly they may

become carnivorous when other food fails, but many are undoubtedly entirely so. The herbivorous species attack a variety of plants, notably oranges. Hibernation is almost invariably in the egg state, and there is only one generation a year. Locustids may be found on trees, shrubs, bushes, and tall weeds and grass. Some species live in caves, and have very long antennæ and legs, wings and auditory organs being absent. Some species burrow in the ground. Most are nocturnal, living in concealment during the day, but some are truly diurnal. Some species have been seen to capture butterflies. Chalcid parasites are said to destroy twenty-five per cent. of the eggs of Katydids, and *Eupelmus* is said to be a very efficient egg parasite. Spiders are of some

FIG. 21.—*Tachycines asynamorus.*

importance as checks on the nymphs, and birds and other insectivorous vertebrates are useful on nymphs and adults.

The following list gives an idea of the literature which may be consulted: Kirby's Catalogue; Lucas, *British Orthoptera*; Caudell, *Gen. Ins.* Fasc. 72 (1908), 138 (1912), 168, 171 (1916); Karney (1907), and *Gen. Ins.* Fasc. 131, 135 (1912), and 139, 141 (1912); Bolivar (1907); Allard (1914); U.S. Dept. Agri., *Bull.* 256; Agri. Expt. Sta. Agri. Coll., Colorado, *Bull.* 101.

Only ten species are indigenous to the British Isles, and three have been introduced. Locustids are rarely serious pests

Most of the vegetable feeders are injurious to a certain extent, but they are not in the same class as Acridiids in this respect. Some forest trees suffer from Locustid pests, but the principal economic species are the Katydids which do considerable damage to young green oranges. The Western Cricket in the United States (*Anabrus purpurascens*) sometimes causes serious damage. In California the Sand or Jerusalem cricket (*Stenopelmatus irregularis*), which is wingless and amber-coloured, spends most of its time underground during the day, making excursions at night. It is often quite plentiful in the autumn and early spring and does some damage to potatoes, gnawing through the tubers. Most of its injury is confined to freshly broken land. *Schizodactylus*, another burrowing form, does much damage by boring its way through the roots of plants in India. Both *Anabrus* and *Schizodactylus* are normally carnivorous, and damage

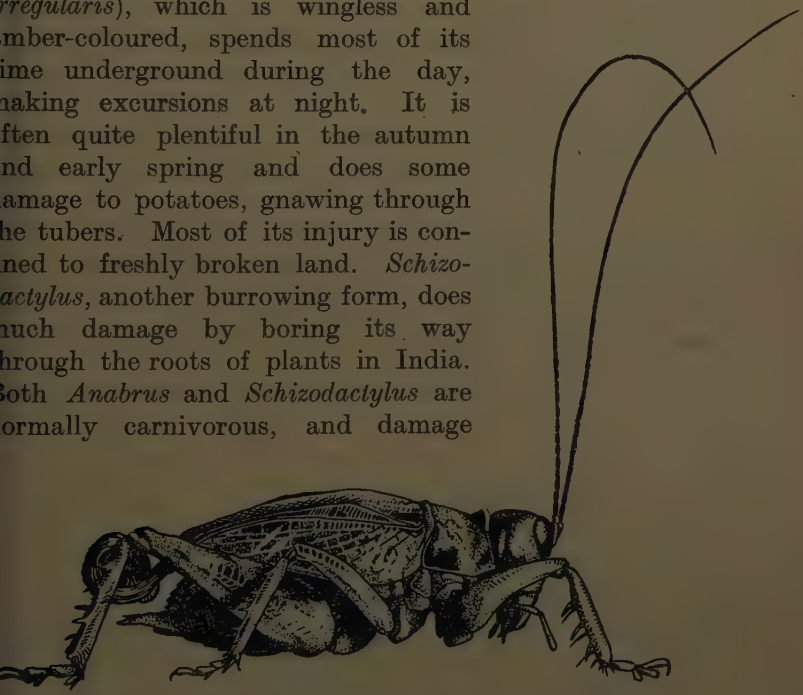


Fig. 22.—*Schizodactylus monstruosus* (about natural size).

crops in the pursuit of their prey. *Ephippiger* occurs on vines in Europe. The wingless insect known as *Tachycines asynamorus* is to be found in glass-houses in England, imported from the tropics. It is apparently carnivorous and useful. The most beautiful orthopterous insect in Great Britain is the large green *Phasgonura viridissima*, the others are most common in the Isle of Wight and the South Coast.

Control measures are rarely adopted, the damage done not being enough to justify expenditure in preventing it. Arsenical

washes have had some success in treating Katydids, whereas cultural methods would help to control the burrowing forms.

Grylloblattidæ.

Cerci with eight joints. Tarsi five-jointed. Asymmetric ovipositor of six processes. Legs cursorial.

A family formed by E. M. Walker (*Can. Entom.* xlvi, 1914, p. 93), for an insect found by him in Alberta. Two females were discovered: the family differs from other *Orthoptera* in having running legs but a well-developed ovipositor; its five-jointed tarsi and eight-jointed cerci differentiate it from the

Fig. 23.—*Grylloblatta campodeiformis.* (× 6.)
(Adapted from Walker.)

Acridiidæ, *Locustidæ*, and *Gryllidæ*. Chopard (1920) discusses the position of the family in relation to *Orthoptera* on the basis of the structure of the apical abdominal segments. Walker (*Can. Ent.* LI, 1919, p. 131) describes the male and immature form. *Grylloblatta campodeiformis* is the known species, found "running about like centipedes under the stones of a talus slope at an altitude of about 6,500 feet."

Gryllidæ (*Achetidæ*).

Crickets.

Antennæ generally long and slender; tegmina angled; tarsi three-segmented. Auditory organ on fore tibia. Ovipositor usually long, round, and spear-like.

Grotesque in form and habits, and containing few beautiful species, this family is made up of a number of remarkable insects whose affinities are little understood.

The crickets are medium-sized insects, whose tegmina tend
› roll up laterally at their extremities. The antennæ are
enerally longer than the body and there are many wingless
›ecies or forms in which the wings are much reduced. In
abit Gryllids are nocturnal, being rarely seen abroad in day-
ght. Cryptic colouring is the rule, but the tree crickets are
f a greenish white hue. *Cylindrodes* is round and burrows in
lants in Australia. Special arrangement of legs, to pack
iem closely to sides, enables it to burrow. Many more are
›und in warm temperate and tropical climates than in colder
egions.

The prothorax is square, the abdomen is generally round and
›ovided with large pleuræ. Very long cerci are present, which

FIG. 24.—*Gryllus domesticus.* (× 2.)

re almost always flexible, hairy, and unsegmented. Anal
ands giving a foul-smelling secretion are sometimes present.
he mouth-parts are hypognathous, and of the ordinary
andibulate type common to the Orthoptera. In the majority
Crickets the mandibles are decidedly carnivorous in character
nd in the larger species are capable of inflicting a painful bite.
he head is generally large and rounded, while the vertical
›ns is separated from the vertex by a narrow rostrum.
›mpound eyes are present, together with three ocelli. Many
rms, however, have the ocelli in an imperfect or rudimentary
ate. In many cases the antennæ attain quite disproportion-
e dimensions. The tegmina are never large or ornamented,
nd contrary to the bulk of the Orthoptera the right tegmen
›erlaps the left. It has been observed, however, that this
ay vary even in the same species. The inner portion lies
›t on the back, while the outer or anterior portion is folded

at right-angles along the sides, forming the angled tegmina characteristic of the family. The horizontal portion is modified for stridulation. The wings are delicate and of fairly large proportions, and are often rolled up at their extremities. In many the rolled portions project beyond the body and look like an extra pair of cerci, and may in fact act as tactile organs. Generally they are longer than the tegmina, but they are often absent, and may be fully developed or abortive in the same species.

The portion which projects beyond the tegmina is not hardened. The legs generally are normal, but the fore-legs are modified for digging in some, while in others the hind-legs are reduced. The hind tibia is furnished with strong spines. The first tarsal joint is long and terminates in two spines between which the small second segment is often concealed. There is no pulvillus. Some exceptional forms do not conform to the rule of these tarsal segments. Owing to the large abdominal pleuræ the spiracles are prominent. The sub-genital lamina generally carries two short styles. The ovi-positor is prominent and usually points upwards, but is not exserted in two sub-families. The male often has the tegmina applied more closely to the body than the female, and in *Oecanthus* the tegmina are broader.

The alimentary canal is short and carries a crop and small gizzard. Two hepatic cæca are present, and numerous Malpighian tubules are found. In Gryllotalpa the latter are arranged fanwise. The canal is enlarged posterior to the Malpighian tubules in some. Very little is known of the internal structure of crickets. The stridulating apparatus is very similar to that found in the *Locustidæ*. Both tegmina are provided with a series of ridges or projections on the under-surface, marked by a depression above.

The tegmina are vibrated very rapidly, and the "file" is thus rubbed over a corresponding ridge on the upper surface at great speed. A very piercing note is produced, which in some species can be heard a mile away. In *Brachytrypes* the tegmina are held at an angle of 60°, while stridulation is in progress, and remain at that angle during the temporary cessation of the "song." Normally sound-production organs are confined to males. During copulation the male creeps

beneath the female and extrudes the spermatophore, which acts as the copulatory organ. This organ consists of a muscular-walled vesicle with a small white papilla at the free end, and a chitinous lamella at the other, in the centre of which is the opening of a tube leading to the hollow interior. The lamella carries hooks to secure the spermatheca within the vulva. The pedicel is attached just below this point. Little is known of the life-history. About three hundred eggs are laid. They are cylindrical, slightly reniform, and longer than broad. They are laid in bunches, and when first laid are soft and whitish, changing to darker hues as they mature. In burrowing forms they are laid in the ground; *Brachytrypes* places them half-way in the earth at the end of the burrow, each in a separate place. *Oecanthus* places its eggs singly in the stems of trees and shrubs, preferring the annual growths. The embryo lies with its back against the concave side of the egg-shell. Nymphs are similar to adults except for the wings, and the sexes can be distinguished at very early stages. For a time the burrowing species live in the parent burrow. Wings appear about the third instar, the whole development extending from five to possibly twelve ecdyses.

FIG. 25.—Spermatophore of *Gryllus campestris*—lateral view. (After Lespès—somewhat simplified.)

Gryllids are omnivorous feeders, but confine themselves mostly to animal matter: some are definitely herbivorous. They feed at night, burrowing forms taking their food down into their tunnels. Cannibalism is frequent, and cast skins are eaten. Hibernation takes place as an egg in most cases, but may occur in the nymphal stage. There is usually only one brood a year, but there may be two. Crickets live in concealment during the day. The majority are ground-dwellers, and they include many burrowing forms. Some, such as the tree crickets, inhabit trees and shrubs. *Gryllus domesticus*, the common house cricket, is abundant in many

old houses and buildings where constant warmth is obtainable. Several species of *Sphex* are predaceous on crickets. Chalcids and Proctotrypids are parasitic on the eggs of *Oecanthus*, and an unidentified Dipterous parasite has been recorded in the nymphs of the same genus. A species of *Mermis* has also been noticed. Flooding appears to kill numbers of the burrowing species, probably acting as a check more by turning them out of their burrows so that crows and other birds can catch them than by actual drowning. Lizards and other insectivorous animals also play their part in keeping members of this family in check.

The following are the principal works dealing with the family generally or with individual species: Lespès (1855); Kirby's Catalogue (1904–1910); Lucas, *British Orthoptera* (1920); Walker, *Canad. Ent.* xxxvi, p. 142 (1904); Ghosh, Mem. Dept. Agri. India, Vol. vi, No. 3 (1912); Parrott and Fulton, N.Y. Agri. Expt. Sta., *Bull.* 388 (1914); Parrott, Gloyer, and Fulton, *Jour. Econ. Ento.*, Vol. viii, No. 6 (1915); Fulton, N.Y. Agri. Expt. Sta., *Tech. Bull.* 42 (1915); Gloyer and Fulton, N.Y. Agri. Expt. Sta., *Tech. Bull.* 50 (1916).

There are only four British species, a mole cricket, two field crickets, and a house cricket.

The Gryllids are not of first-class economic importance, although great damage is caused by some. Burrowing forms such as *Brachytrypes* cut off young crops and take the spoil below ground, causing considerable damage. The tree crickets (*Oecanthus*) cause considerable damage to fruit trees, bush fruits, vines, and crops of a similar nature, because they carry various bacterial and fungous diseases. In the case of tree crickets control lies in the direction of clean cultivation and the removal of fungous growths which might be spread. Twigs in which eggs have been deposited may be cut off, and spraying with arsenical washes has met with success. Winter washes have no effect on the eggs. Members of this sub-family are beneficial to some extent, eating considerable numbers of coccids and other small pests. Cultivation must form the chief means of preventing damage by burrowing crickets, but poisoned baits should be successful, especially if put down after the land has been well cleaned, so that little alternative food is available.

The family is divided into seven sub-families, which vary so much in character that some details may be given of each one. In many instances it is wellnigh impossible to grade certain species of Gryllids and Locustids into separate families.

Tridactylinæ. These resemble mole crickets, but are very small. They are generally found in alluvial silt areas, near big rivers, jump well and burrow quickly. The fore-legs, as in the

Fig. 26.—*Tridactylus* sp. (× 8.)

next sub-family, are specially modified for digging. The ovipositor is not exserted, and the alar organs are imperfect. The hind tibia terminates in two processes, but the tarsi are abortive. Near the extremity of the tibia are some plates which can be extended or retracted at will. The antennæ are composed of only ten segments, and there are no auditory organs on the legs. In both sexes there are four hairy appendages on the anal segment, two cerci above and two articulated extensions of the segment below. It is difficult to distinguish the sexes.

Fig. 27.—*Gryllotalpa africana*. (× 2.)

Gryllotalpinæ. The mole crickets are an interesting group of wide distribution, of a larger and stouter build than the last sub-family. The fore-legs are modified for digging, the tibia and tarsus being arranged to serve as shears for cutting through roots. The first and second joints of the tarsus are furnished with strongly chitinized processes which pass over the edges of

the teeth on the tibia when moved. These insects prefer moist situations, like water, and are said to swim well. Auditory organs are present in the usual place, but are concealed by a deep fold. The tegmina are small, but the wings are of ample size. A vertical shaft is sunk in the ground and horizontal galleries are made in all directions. The œsophagus is elongate and carries a pouch on one side. The gizzard is embraced by two lobes of the stomach, which is continued back as a thin neck, gradually becoming larger. Below the stomach, on the neck, a pair of branching organs is situated which is thought to be peculiar to the sub-family.

It is believed that these insects are mainly carnivorous, but they can eat vegetable as well as animal matter. Most of the damage done to crops, which is considerable, is by cutting through the roots, probably in search of worms and larvæ. Two to four hundred eggs are laid in the burrow, and it is said that the female carefully watches them until they hatch, and even supplies the young nymphs with food until after the first moult. It is stated that the young nymph's digestive system is not fully developed when it hatches, which it does some three to four weeks after the egg is laid. The eyes are reduced, as are the hind-legs, which are not much used for leaping. In Porto Rico, *Scapteriscus vicinus* attacks cotton, and may become serious elsewhere in the tropics. Mole crickets are garden pests.

Myrmecophilinæ. Small oval-shaped crickets, which are found in ants' nests in Europe, Asia, and America. They are apterous, have thick antennæ, and a short broad abdomen. The eyes are abortive, and the ovipositor is short.

Gryllinæ. This is composed of the true crickets, which may be surface-living or burrowing in habit. The burrowing forms dig with their jaws, biting out the earth and throwing it out behind with their legs. When too deep down to do this they push the earth out with the head. The domestic cricket may be taken as a representative type, and is widely distributed in both the New and Old Worlds. It is sometimes found out of doors, but does not live a truly wild life, and warmth is essential for its well-being. The wings are long and project backwards like cerci. The adult male alone produces the chirping or other note.

Oecanthinæ. The tree-crickets are delicate and slender

insects, found in the warm temperate and the tropical regions of both hemispheres in some considerable numbers. They have transparent tegmina and whitish-green colouring. They are to be found on trees and bushes, and make their presence known at night by a shrill and persistent note, the rapidity of which has been observed to be closely related to the temperature. The female starts egg-laying in late summer or autumn by tearing off pieces of the epidermis with the mouth-parts. The ovipositor is then placed in the small depression made and pushed in at right angles to the stem. After drilling for the full length of the ovipositor the hole is widened by swaying from side to side, and drilling out a cavity. It is then partly withdrawn and the egg laid, after which the hole is filled in by

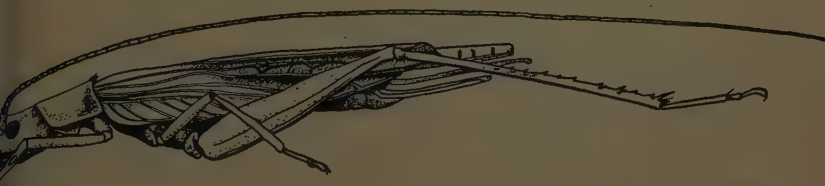


FIG. 28.—*Oecanthus nivens* ♀. (× 5.)
(After Parrott and Foulton—somewhat simplified.)

drilling into the sides of the hole and pushing the loose material down on top of the egg. Loose epidermis is then torn off again with the mouth-parts, and the whole finished off with salivary secretion. Eggs are laid singly and have a cap on the cephalic end which is pushed off when the young nymph emerges. The nymphs are active at night and feed largely on small insects. The cast skin is eaten after each moult, of which there are four, the fifth giving the adult cricket. In addition to the musical powers possessed by the male, a gland is situated on the metanotum which is exposed when the tegmina are raised during stridulation. The female climbs on the male's back and eats the secretion of the gland. Copulation takes place in this position, when the spermatophore is introduced.

During the later stages of the life-history tree-crickets change their feeding habits from a carnivorous diet to one consisting largely of fungi. They thus become dangerous as carriers of

fungous diseases, and were it not for this the good done by feeding on injurious insects would probably exceed the damage done in ovipositing and feeding on portions of the host plant.

Trigonidiinæ. In appearance these insects are like beetles, with horny arched tegmina. The hind femora are thick to the apex, and the second tarsal joint is cylindrical.

Eneopterinæ. Delicate elongate insects, many of which are apterous. The hind tibia has five serrations only with no spines. Most are clothed in scales. Extremely little is known of either of the last two sub-families.

ISOPTERA

White Ants. Termites.

Soft insects with simple antennæ, two pairs of equal membranous wings lying flat on the abdomen, and shed by means of a suture at their base, or entirely wingless. Biting mouth-parts. Ten abdominal segments. Anal cerci present. Social.

The Termites have now been promoted to a separate order, but were formerly the family *Termitidæ* of the order *Corrodentia* or *Pseudoneuroptera*.

It is unfortunate that the name White Ant has stuck to these insects, but Termites can be distinguished from ants by having the abdomen sessile on the thorax, and by not having the abdominal nodes, universal in ants. The usual colour is whitish, darkening through various shades of brown to black. Four types are commonly seen; the winged adults with wings longer than the body, the "royalties" or "kings" and "queens" which have the bases of the wings only as horny flaps; and soldiers, and workers, both wingless. The soldiers are noticeable on account of their large mandibles. Rarely is any type fully chitinized. The various individuals make up a more or less large community, and live a social life in a concealed nest, or in the huge mounds familiar in many parts of Africa and the East. Very few live in warm temperate regions and none in the temperate regions, the vast majority being confined to the tropics and sub-tropics.

The head of the soldier termite is well chitinized, and in this type the mouth-parts are prognathous, whereas in all other forms they are usually hypognathous. The mandibles are short with the inner edge armed with teeth, which are generally uneven in number on the two. In soldiers the mandibles are developed to an enormous size, being often as long as the whole of the rest of the body. The maxillæ end in two curved points, the labium is large, especially in workers, and the ligula is channelled, but not divided, with two lobes on the extremity. The labrum is of characteristic shape in different genera. The

head is large, especially in soldiers, and is articulated with the thorax by two large cervical sclerites on each side. There is a broad clypeus having a median line in some, and the gulæ are large and vary according to the genus. Eyes are generally absent, but the winged adults possess compound eyes, and they are present in a reduced or rudimentary form in the harvesting Termites. Some soldiers have compound eyes, but they are not pigmented. Two ocelli at most are found, while many have a median opening, or fenestra, on the head, which is the opening of a frontal gland whose secretion is used in defence. The antennæ are simple, composed of nine to thirty-one segments: the number of segments being less in the nymph, the worker, and the soldier. The number of segments in the nymph increases with the general growth by the division of the third segment. The antennæ in many are fitted with sensory hairs, and are often observed to be mutilated in the reproductive forms.

Fig. 29.—Worker of *Eutermes monoceros*. (× 20.)
(Modified from Bugnion.)

The wings are unlike those of any other insect, and are divided into two parts by a suture at the base. They are used for a single flight only and then shed by breaking them off short at the suture, the basal portion remaining attached to the thorax. The neuration is simple, but varies in different species. Some soldiers have vestiges of wings, although the rule is that soldiers and workers are always wingless. The legs are formed for running, and have the tibia generally longer than the femur. The tarsi are three- or four-jointed, the apical joint being the longest and armed with two claws. The coxæ are large, free and exserted. The body is often wholly clothed in hairs. The prothorax is well developed with a pronotum which varies in size and shape. The episterna are long and

chitinous, but do not quite meet, and are in contiguity with the cervical sclerities. The epimera are large, and the prosternum is usually almost entirely membranous and varies according to the species. The mesosternum forms a large depressed fold; the metasternum is terminated posteriorly by a sclerite of variable form. The abdomen consists of ten segments, but the first is indistinct. The apical plate is divided into two, each half bearing a cercus of two to six joints, but the form of the plate varies with the species and sometimes with the sex. In the male, and sometimes in the female as well, a pair of very small styles can be made out close to the centre of the posterior edge of the ninth segment. There are two or three thoracic and seven or eight abdominal spiracles, but in the fertile queen there are usually only six of the latter.

Fig. 30.—Soldier of *Termes Horni*. (× 6.)
(Modified from Bugnion.)

The sex differences in termites are enormous. After egg-laying starts the abdomen of the female enlarges to a great extent, even up to twenty or thirty times its original size. The adult male also increases slightly in size after repeated copulation. The alimentary canal is coiled. A slender œsophagus enlarges abruptly into a crop, which, however, may be absent. The Malpighian tubules may be fewer in number in the adult than in the nymph, but there are generally four to eight. There are five hepatic caeca. Posteriorly to the Malpighian tubules the proctodeum is enlarged into the so-called "paunch," which is probably connected with the wood-eating habits of the insect, and which contains a large number of protozoa. Salivary glands and reservoirs are present and are very large in some. The fat body is greatly developed in all winged forms. Small quantities of a fluid which is capable of corroding metal and, it is said, glass, are emitted from special structures in the rectum.

Although the eyes as a whole are imperfect, the protocerebron is very well developed, as are also the sympathetic system and the corpora allata, the latter being considered to function as ductless glands. There are three thoracic and six abdominal ganglia, the abdominal ones in a fertile female often enlarging so much as to rival the cephalic ganglia in size. An auditory organ has been shown to be present by Müller. Communication between two individuals seems to be effected when they are alarmed by means of peculiar jerky movements. Each testis is formed by eight capsules, opening into the vasa deferentia, which converge to form a short ejaculatory duct: with the vesiculæ seminales situated at the point of convergence. The number of egg-tubes in the ovary varies greatly according to the species, age, and fertility of the individual. The tubes open separately into the oviducts, which unite to form a short uterus to which is joined a spermatheca. Near the extremity of the uterus is situated a much convoluted tubular colleterial gland. The male genital organs increase slightly, and the female organs enormously, after the first copulatory act. The eggs laid by the queen termite are all fertilized, and are sometimes laid in enormous numbers. They are white or yellowish and slightly reniform, and are carried away and tended by the workers. Nymphs of two forms, with disproportionately large heads, emerge. The two forms can be distinguished by the form of the brain, eyes, and genital organs, and are destined to have totally separate lives. One form becomes workers and soldiers, the other results in fully sexed reproductive individuals. It will be seen that the reproductive processes of termites are thus extremely complicated, for the different grades of the community are not, as was thought, brought about by careful feeding or special conditions, but are sharply divided in the egg stage itself. Furthermore, there is no difference due to the fertilization or non-fertilization of the eggs as in bees, because all the eggs are fertilized.

The majority of nymphs are without eyes on emergence. The metamorphosis is slight and gradual, more in soldiers than in workers. The nymphs undergo about four ecdyses, the workers and soldiers completing their development in a year, while the reproductive forms may take two years to attain maturity. A quiescent stage precedes the final moult.

There are roughly three castes in a colony, the reproductive pair, workers and soldiers. The differences between the workers and soldiers are apparently not produced by differences in food, but are possibly due to inherited characters. The actual functions of these two are not strictly adhered to. The reproductive pair consist of a de-alated male and female, known as the king and queen. They are responsible for producing all the inhabitants and for keeping up the colony. The queen increases enormously in size and is long-lived, taking in some cases years to reach the maximum size. On account of her size the queen is often incapable of leaving the nest. In some cases the royal pair are imprisoned in a special cell, but the royal cell is not always present. Copulation is frequent, and it would appear that the male lives as long as the female. They are both tended by the workers, who feed them and carry away the eggs. The workers also appear to clean them carefully by licking their bodies, but this has been explained by the fact that certain exudates from the queen's tissues are greedily sought after and eaten by them, but no histological evidence can be adduced in proof of this. In addition to the royal pair several individuals of a type known as complementary or neoteinic royalties are kept in the colony. They are used to replace one of the royal pair should it die suddenly, or for dividing up the colony into more than one complete unit, as is often done. The neoteinic royalties are nymphs of both sexes, drawn from the penultimate instars, in which the sexual organs are specially advanced, so that when required they can rapidly be brought to full sexual maturity, everything but the sexual organs remaining in the nymphal state. They are usually blind and wingless, but are nevertheless adults in which one set of organs has been developed rapidly at the expense of others, and cannot be considered to be pædogenetic. In many instances several neoteinic forms may be present in a colony together with a normal royal pair, while in some nests the colony is carried on solely by these forms.

Thompson recognized three forms of reproductive individuals: the de-alated adult developed from " nymphs of the first form," a second form with short wing pads, no functional eyes and developed from " nymphs of the second form," and an apterous third form with only traces of eyes. A curious feature of the

second form is that it breeds true and never produces nymphs of the first form giving rise to winged adults. The third form also probably breeds true to type. At any one time males of the first form may be found with females of the second form. The actual number of distinct castes and reproductive forms present at the same time in one colony has not by any means been worked out for even a few of the species of termites. As many as fifteen forms have been recognized in a single colony owing to the presence of different castes, young in various stages of development, neoteinic forms, and so on. The whole question is further complicated by the fact that more than one species may be present in a colony.

FIG. 31.—Imago of *Coptotermes Ceylonicus*. (× 8.)
(Modified from Buguion.)

The workers form the most numerous portion of the colony, and occur in most genera except the Kalotermitidæ. They are blind and wingless, and are developed from either male or female nymphs with retarded sexual organs. Their duties appear to consist of building and repairing the nest, and all other forms of work such as food-collecting, tending the nymphs and looking after the royalties. In addition they seem to be the most efficient fighters, and appear to control the whole social system of the colony. They are very similar in the different species and undergo very little metamorphism. Soldiers occur in all genera except the Anoplotermes, and are

really more highly specialized workers. They are formed from nymphs of either sex and are blind like the workers, although some have eyes in a very rudimentary form. The head is abnormally large and fully chitinized, with enormously developed mandibles, which are of use in determining the species. In fact, unlike the workers, the soldiers are fairly typical of the species, and have been largely used in classification. In some, the so-called *Nasuti*, the mandibles are modified to form a kind of beak through which a protective and sebific fluid can be exuded at will. In some species two forms of soldiers are known, and some have small wing pads. There is a certain amount of evidence that soldiers which are unsatisfactory in their development are killed off. Their function is presumably protective, but this duty is far more efficiently carried out by the workers, and their chief usefulness would seem to be in assisting the workers and as scavengers in clearing up—generally by eating—all refuse, and in killing and eating all those individuals which have the misfortune to go sick or die. Both workers and soldiers have been seen with well-developed reproductive systems which show no sign of degeneration or arrest in development, and it is recorded that certain abnormal soldiers with wing pads are capable of producing fertile eggs which hatch to normal caste nymphs.

At certain times of the year, depending on a proper amount of humidity and on a sufficiently high temperature, large numbers of nymphs arrive at full maturity. As winged adults they remain in the nest for a few days and then emerge from the colony in huge swarms and take a flight of short duration. They then drop to the ground, having, it is said, already paired off to some extent in the air. Soon after alighting, and when each one has found its mate, they cast their wings by breaking them off at the suture at the base. The female then hunts round for a safe spot under rubbish or fallen leaves and digs a small hole. This procedure is an attempt to form a new colony, and copulation takes place about a week after emergence. It is said that actual copulation does not take place at this time, but that the eggs are fertilized after being laid. It appears, however, that on examination of the spermatheca at this time, the spermatozoa can always be found. These eggs, of which a small batch only is laid, hatch to workers and a few

soldiers, which are cared for by the royal pair until they are fully developed, which takes about six months. During the whole of this time no more eggs are laid by the female, and the royal pair forage for themselves, or subsist to a great extent on the nourishment stored within their bodies. As they are usually so entirely dependent on workers it is remarkable that they should be capable of living on their own for so long a period, but they may possibly be temporarily adopted by other colonies. In this way a new colony is established, at least in theory, for very few, if indeed any, ever succeed in establishing themselves. The vast majority are destroyed during the swarm, every insect-eating animal collecting from miles around.

In addition to water, six varieties of food are consumed by termites, the principal one of which is probably wood. Proctodeal food is obtained by one termite from another by stroking its posterior end with its antennæ, and this food is passed on from one to another until it has no nutritive value left and is deposited outside the nest. Stomodeal food is regurgitated by the workers, and is probably reserved for the royal pair and the nymphs. Cast skins and dead bodies, as well as the sick, are all eaten by the soldiers. Salivary secretion is occasionally used by the same individual which produces it, but is generally reserved for feeding the young nymphs. Fungi are largely used as food, there being a special chamber in the nest where one particular species of fungus is grown on chewed wood by the workers, which attend carefully to its cultivation and weed the beds regularly. This food is used for the nymphs and royalties. There is no hibernation among the termites, nymphs of all stages being present in the colony all the year round, and the production of eggs going on continuously once a colony is formed. They live entirely in nests constructed by the workers, and shun all light and dry air, even going to the trouble of making covered passageways wherever they go. In some cases aerial passages are constructed to places above ground-level. Certain types, however, such as the harvesting termites, come out into the open, and many cases are recorded of long columns being seen on the march, the soldiers climbing grass stems on the flanks and acting as scouts. The form of the nest varies with the particular species, and is of numerous

grades, from underground burrows to the colossal mounds of some tropical species which are sometimes twenty feet in height. Some construct nests hanging from fence posts, rather like wasps' nests, with aerial galleries extending to the ground.

A large number of termitophilous animals have been recorded, including other insects, lizards, rats, and so on, but it is doubtful if these act as checks. A genus of termites, *Eutermes*, apparently lives as a guest in the nests of other species. A special type of fungus is not uncommon on the abdomen of soldiers and workers; nematodes have been observed infesting the body cavity, and mites have been observed externally. A few protozoan parasites have been recorded, but there seem to be large numbers of protozoa present in the "paunch" of wood-eating forms, and these probably live in symbiosis,

FIG. 32.—A Queen Termite (nat. size).

assisting in the digestion of wood. The real enemies of the termites, apart from the insectivorous animals and birds, which destroy practically all the winged forms as they emerge, are ants. Their relations with the latter appear to be perfectly pacific even when they have galleries crossing each other's preserves, but directly the termites' nest is broken open by some other agency, the ants swarm in and destroy large numbers.

An enormous amount of literature has been written on termites, both on account of their remarkable life-histories and social instincts, and owing to the extent of their injuries. The following are the most important recent publications: Desneux, *Gen. Ins.* Fasc. 25 (1904), Wasmann (1904), Escherisch (1909), Holmgren (1909, 1911, 1912, 1913), Snyder (1915, 1916), Imms (1916), Thompson (1917), Banks and Snyder (1920).

Dr. Thompson was engaged on a book on termites when she died, and it is hoped that it will be published.

There are no British species, but the number of world species

is probably over nine hundred. Desneux lists nearly three hundred and fifty known species divided into three sub-families.

The economic importance of the order is considerable, great damage being done to timber, especially the timber of houses. Books and leather are soon eaten if left in damp places, and even timber in forests may be rendered unfit for market. Termites also attack wheat, sunflower, groundnut, and sugar-cane, and are apt to be a serious pest on cacao. Fruit trees are attacked, galleries being made from the roots up the trunk in the case of apricot, cherry, lemon, peach, pear, orange, etc. The harvesting species carry away alfalfa, oats, wheat, while considerable damage may be done to seedling plants and greenhouses. It is stated that these insects never attack healthy growing plants, but that there is some disease sapping the vitality of wheat, etc., before they attack it, and that they start boring into fruit trees at some point where the wood has decayed, and work on from there to the healthy portions. In this way control may lie in the direction of keeping up the full vigour of the plants by good cultural methods.

It is on timber which has been made into buildings or otherwise worked that the termite does most damage. In all termite attacks, one of the great difficulties lies in the fact that they work unobserved, the damage being complete before it is realized that anything is wrong. This damage may be very rapid: in Dr. Mitchell's Cairo-to-Cape flight, the wood skids and frame of the aeroplane were attacked in one night's halt. Certain woods, such as teak (*Tectona grandis*), greenheart (*Nectandra rodiaci*) and mahogany, are highly resistant to termite attack. When other woods are used where there is a likelihood of termite attack they should be kept absolutely dry, and where possible they should be sunk in concrete and not in the ground. Special attention should be given to ventilation, and wood should be excluded from foundations, brick or concrete being used in place of it. It is recorded that termites have actually bored through cement and lead, so that where they abound wood should in addition be treated with creosote, corrosive sublimate, or other such preservatives. They are capable of penetrating dry hardwood if they have access to moisture elsewhere.

In protecting orchards and crops, care should be taken not

to plant at once on recently cleared land which has abundant food supplies present in the form of decaying wood. The ground should be kept perfectly clean, and if termites are numerous in a farming district it may be advisible to discontinue the ploughing in of stubbles and the use of farmyard manure. Such land is generally plentifully supplied with humus and would not lose its fertility for some time if artificial manures were used judiciously. All damaged wood or plants should be removed and burnt and the nests should be sought out. These can be recognized by the accumulations of frass and covered ways, where they are not built above ground, and by watching for the emergence of the winged adults. Kerosene poured into the nests is effective in destroying them, or some material soaked in carbon disulphide may be inserted in the main burrows. An efficient way of wiping out a nest is by the use of a closed cylinder which has the ends removable, or is fitted with a door, and which has a grating across the centre inside. An air-pump is fitted to the bottom and an outlet tube to the top. Red-hot charcoal is placed on the grating, and on this is placed a mixture of arsenic trioxide and sulphur. Air is then blown through and the arsenic trisulphide which is formed is forced through the outlet tube in the form of vapour. The tube is introduced into the termites' nest and quickly kills all the inhabitants. The apparatus can be carried about easily and is a convenient one to use where it is wished to destroy a large number of nests. Where crops are attacked which can be irrigated, a very small percentage of kerosene in the irrigation water will destroy the termites without affecting the plants.

ZORAPTERA

Small, generally wingless, terrestrial insects; agile and predaceous. Antennæ nine-jointed. Short one-jointed anal cerci.

This small order, comprising only one genus, was founded by Silvestri in 1911, from material sent from Ceylon by E. E. Green.

These insects are found only in warm countries, having been taken, up to the present, only in Java, West Africa, Ceylon, and U.S.A.

The *Zoraptera* were always described as an apterous order till 1918, when winged specimens of two distinct species were discovered. As regards their evolutionary interest, Dr. G. C. Crampton says (1920):—

"Taking their anatomy as a whole, I would regard the *Zoraptera* as intermediate between the *Isoptera* and the *Plecoptera*, with their closest affinities tending slightly toward the side of the *Isoptera*, although the balance of characters is so evenly divided between the two groups, that it is very difficult to decide whether the *Isoptera* or the *Plecoptera* are the nearest relatives of the *Zoraptera*. . . .

"On the other hand, the *Zoraptera* themselves are very like the ancestors of the *Psocidæ*, so that they are extremely important insects for a study of the evolution of the higher forms such as the *Hymenoptera*, *Neuroptera*, etc., whose ancestors were undoubtedly extremely closely related to those of the Psocids."

The body is elongate and flattened, bearing numerous hairs. The head is of about the same width as the prothorax, and somewhat narrowed in front; it is inclined downwards from the thorax. Large, moniliform antennæ are present, nine-jointed, and expanding towards the apex, with joints five to nine, sub-conical in shape. The mandibles are strong and of the biting type, with well-developed teeth; the maxillæ are distinctly separated into inner and outer lobes, with five-jointed palps; and the labium is bilobed and bears

three-jointed palps. Compound eyes and ocelli occur in the winged forms, but are absent in the apterous forms. Of the thoracic segments, the prothoracic is the largest. The legs are uniform, of the running type, with two-jointed tarsi bearing two claws and a setiform empodium. Thorax and abdomen are of about the same length. The abdomen consists of ten distinct segments which broaden out from the first to the eighth ; it possesses a pair of short, single-jointed cerci.

The alimentary canal is simple and straight for the greater

Fig. 33.—*Zorotypus hubbardi* ♀. (× 20 approx.)
(After Caudell.)

part of its length. The fore-gut reaches back about half-way along the abdomen, narrows down and then expands into the hind-intestine or true stomach. The number of Malpighian tubules is rather uncertain, but is probably six. *Zoraptera*, up to the present, have been found chiefly under the bark of trees. They are social in habit, and in the variety of individuals found in one nest are very reminiscent of the *Isoptera*. In one of the newly discovered species possessing winged forms (*Z. hubbardi*) the following types of individuals are found :—

1. Chitinized adults, whose fully expanded wings had been

shed at the base, after the manner of termites; with well-developed eyes and ocelli.

2. Slightly chitinized nymphs with nine-jointed antennæ, subcutaneous eyes and ocelli, and possessing partially developed wing-pads.

3. Non-chitinized, wingless nymphs, without eyes or ocelli, and with eight-jointed antennæ; otherwise similar to the adult.

4. Non-chitinized wingless adults, without eyes or ocelli, and with nine-jointed antennæ. Closely resemble the nymphs of type two.

Of the winged form, only females have as yet been taken.

These insects have not yet been bred out from the egg, but on several occasions a single egg has been found near a female which is in all probability that of *Zorotypus*; it is $\frac{5}{8}$ mm. by $\frac{3}{8}$ mm., and has a sculptured surface; its size indicates that the eggs are laid singly.

The sole family included in this order is the *Zorotypidæ*, with one genus, *Zorotypus*. Silvestri first described the order in 1913, and wrote an account of *Z. neotropicus* in 1916. The new winged forms were dealt with by Caudell and Crampton in 1920.

PSOCOPTERA

Book lice. Death watches.

Small soft insects with two pairs of membranous wings having few cross-veins; fore-wing larger than hind-wing. Antennæ filiform. Mouth-parts biting. Prothorax small. Tarsi two- or three-jointed.

This order formerly comprised the family *Psocidæ* in the order *Corrodentia*. It is referred to in modern American text-books as the order *Corrodentia*.

In addition to the usual winged forms, many are known which are wingless, or in which the wings are unsuited to flight. The winged forms have a small prothorax which is concealed between the head and the large mesothorax, which, again, is fused to the metathorax. In the wingless forms, however, there is a larger prothorax and a small mesothorax. When at rest the winged forms close the wings along the body in a sloping position, with the posterior margin uppermost.

The colour is usually whitish, grey, or brown, but some tropical species are very brightly and artistically coloured. Members of the order are probably more abundant in temperate than in tropical regions, although the attractiveness of the tropical species has led to greater numbers being collected, thus increasing the number of brown species in these regions over the known species in the cooler parts of the world. The Hawaii Islands are particularly rich in representatives of the order, while the largest species known, which has a wing expanse of an inch and belongs to the genus *Thyrsophorus*, has its home in Brazil. Large numbers are preserved in amber. The mouth-parts are hypognathous and of the biting type, a curious feature being the unusual formation of the maxillæ. Each maxilla is composed of a fleshy outer lobe, with the inner lobe modified to form a remarkable organ, which was considered by the earlier writers to be a separate appendage, and which was given the name of the "pick" or "rod." The "pick" articulates with the outer lobe by

sliding in it in the manner of a piston sliding to and fro in its cylinder, and is now generally regarded as being the true inner lobe of the maxilla. The suggestions as to what use this mechanism is put have been many, among which may be mentioned the theory that the ticking noise undoubtedly made by some species—hence their name "death watches"—is achieved by tapping the end of the pick on wood. Very possibly the "pick" may be used in puncturing the sporangia of fungi on which the insects feed, but this form of action has not been observed, and the true aim of this modification of the maxilla is shrouded in mystery. The labium has a large mentum and ligula, which is divided into two lobes. The labial palps are reduced to globular lobes placed externally on the anterior portion of the labina. There is a large hypo-pharynx, which is free and has two gland ducts opening on it. The labium and post-clypeus are large, the latter often appearing as if it were inflated. On examination it is found to have several muscles attached to its inner surface, which have their insertion on a plate placed below the anterior portion of the œsophagus.

Fig. 34.—*Atropos* sp.

The head is large and is provided with compound eyes, which are often very convex and developed more in the male than in the female. Three ocelli are present in the winged forms. The antennæ have from eleven to fifty segments. In some species the wings are clothed in scales, so arranged and coloured as to rival even the Lepidoptera in beauty. Wings are absent almost entirely in *Clothilla*, *Hyperetes* and *Atropos*. In some of the apterous species rudimentary processes can be found on the prothorax, which Hagen considered to be rudimentary wings. With only a few exceptions, wings and ocelli are both present or absent at the same time, possibly a case of Mendelian "linkage." In *Mesopsocus* the adult female has diminished wings, whereas the adult male has them more fully developed.

It is always noticeable that even when wings are present and fully developed there is a marked reluctance to use them. The tarsi are generally composed of two segments, but three may be present in some. A peculiar gland of unknown function has been noted at the base of the tarsal claws. Not much is known of the internal structure. There is no crop; there are nearly always four Malpighian tubules; the posterior portion of the alimentary canal is very short. The ovaries are formed by five egg-tubes which all lead into a common oviduct. The accessory glands are somewhat remarkable, consisting of a number of small vesicles, each with a separate duct, enclosed in a sac, but they have not been fully investigated.

The life-history is hardly known. The egg stage mostly persists through the winter in England; they are laid in many cases under silken covers, which are probably spun by glands in the hypopharynx, and then covered by excremental matter. They are placed on the bark of trees or on plants. The nymph is similar to the adult, but has no ocelli or wings at first, and as it grows the prothorax diminishes in size. There are two or more generations a year in warm climates, and the adults often live in small colonies under their spun-silk covers. Their food is apparently animal and vegetable refuse matter, fungi, lichens. In some cases it appears that a speciality is made of the *Uredineæ*, but to what extent is not known. These insects may be found on tree trunks, especially those of the conifers and beech, and sometimes in birds' nests. *Atropos* feeds on pinned insects in collections, and *Clothilla* eats the starch paste used in binding books. It is individuals of these two genera which are said to make noises like those made by the death-watch beetles. Damp air is in all cases essential to their life, dry air, together with strong light, being fatal to them. The action of checks in nature is not known except that the larva of *Croce filipennis* feeds on the household

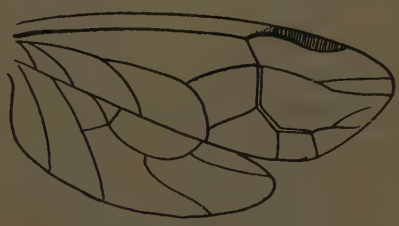


Fig. 35.—Wing of Psocid.

species. There are well over 2,000 species in the world, of which forty are British.

The economic importance of the order may be said to be nil. The household species can be troublesome at times, especially in damp places. As in the case of houses which harbour mites, the prejudices of the occupier largely determines whether the insect is a pest or not. The chief loser from the depredations of these minute insects is likely to be the entomologist himself, if they get into his collection. One species, *Psocus taprobanes*, has been recorded as damaging tea in Assam, but after careful investigation this has been denied. Numerous observations and isolated papers have been written on the order, but up to the present no comprehensive work has been done on them.

References.—Derham (1701, 1704), Burgess (1878), Hagen (1881, 1883), Ribaga (1900), Enderlein (1903, 1904, 1905, 1906), Stager (1917), Menzel (1921), Banks—numerous papers.

MALLOPHAGA (*Lipoptera*)

Biting Lice. Bird Lice.

Flattened, the head large; the prothorax distinct, mesothorax small, the metathorax small and usually fused with the abdomen. Mouth-parts of biting type, mandibles well developed.

The *Mallophaga* appear to be widely distributed over the world, though the tropical fauna is still little known.

There is generally no difficulty in identifying these insects; they are all small and live parasitically on birds and mammals, but unlike the *Anoplura* they do not suck blood, but feed on the feathers or hairs of their hosts. *Mallophaga* are very active, especially in the early stages, and can run with considerable speed.

Fig. 36.—*Colpocephalum* sp.

The head is abnormally large and flattened and often triangular in shape: the antennæ, which are short and composed of from three to five joints, are often concealed in grooves. The eyes are small or absent. The mouth-parts are of the biting type, the mandibles being well developed and toothed; the maxillæ, which bear an inner lobe, are in some families provided with a four-jointed palp. The labrum is large and apparently used as a scraping organ.

The legs, especially the first pair, are rather small; generally speaking, the bird-infesting species are provided with two claws on the tarsus, whereas the mammal-infesting forms have only one claw: there are, however, several exceptions to this rule.

With regard to the internal anatomy, there is little of note;

the nervous system consists of an infra- and supra-œsophageal ganglion, and three thoracic ganglia.

The alimentary canal is simple : there is a long œsophagus, which in some forms is dilated to form a crop ; according to Sharp the posterior portion of the œsophagus connects the crop and the stomach. There are four Malpighian tubules present.

The reproductive system is very simple : in the male there are from four to six testes, and in the female three to five egg-tubes ; the two oviducts unite before reaching the exterior. The eggs are laid singly or in clusters, and are attached by a gummy secretion to the hairs or feathers of the host. Little is known of the early stages, owing to the difficulty of observing the insects under natural conditions.

There is no complete metamorphosis, the young lice on emerging from the egg being very similar to the adult. Besides hair and feathers, *Mallophaga* also feed on dry flakes of skin, and according to Kellogg they will eat dried blood from wounds or abrasions of the skin.

Mallophaga are to be found on almost every kind of bird ; mammals, especially the domesticated species, and certain marsupials, also harbour these insects, but out of the 1,250 known species of *Mallophaga* only about sixty species have been found on mammals. Closely allied species of birds are often infested with allied species of lice. As a general rule, particular species of *Mallophaga* are confined to particular species of host, but notable exceptions occur, especially in the case of birds such as waders, where different genera are often in contact with each other, so that the parasite can readily pass from one bird to another.

Many species of *Mallophaga* are common to North America and Europe.

The *Mallophaga* have been monographed in *Genera Insectorum*, Fasc. 66, by V. H. Kellogg. Among the earlier writers should be mentioned Giebel and Nitzsch, *Insecta Epizoica*, and Denny's *Monographia Anoplurorum Britanniæ*, 1842.

Denny lists about 200 species of *Mallophaga* from Britain, but many of them were obtained from birds which are very rare, or of accidental occurrence in the British Isles.

The economic importance of the order is not very great. Bishopp and Wood (*Farmer's Bulletin*, No. 801, U.S. Dept. Agr., 1919) state that more than forty species of *Mallophaga* are found on the domestic fowl.

Perhaps the commonest species is *Menopon pallidum*, which is found throughout Europe and North America. Although the lice do not suck blood, they often affect the general health of the fowl, with the result that the egg-yield is diminished and the bird is more liable to suffer from disease. Young chickens, especially, are very apt to die when heavily infested with lice.

There are several effective control measures: Bishopp and Wood recommend sodium fluoride dusted among the feathers of the chicken, a pinch of the powdered chemical to be rubbed among the feathers where the lice are most numerous. An alternative method is to dip the chicken into a solution of sodium fluoride in water, the proportion being $\frac{3}{4}$ to 1 oz. of the salt to one gallon of water. Care should be taken that the sodium fluoride does not get into the food of the chickens, as it is poisonous when taken internally.

FIG. 37. — *Mallophaga* eggs on a feather, after hatching. (×10.)

Another remedy is to rub on some vegetable oil, such as olive, gingelly, or ground-nut. This method has been successfully used in India. The "dust-baths" so frequently indulged in by gallinaceous and passerine birds probably checks the numbers of the parasites to some extent.

Kellogg, in *Genera Insectorum*, recognizes two sub-orders and four families; these families are quite distinct both in structure and habits. There are twenty-seven genera and about 1,250 species known; the European and North American fauna has been well studied, but many more species will doubtless be obtained from tropical birds and mammals.

Sub-Order I. *ISCHNOCERA*

Antennæ exposed, filiform, three- to five-jointed. . Maxillary palpi absent; mandibles vertical. Meso- and metathorax fused. Testes, four; egg-tubes, five.

Trichodectidæ.

Antennæ three-jointed; tarsi with one claw. Found exclusively on mammals.

This family contains but one genus—*Trichodectes*—with about forty-five species, of which ten occur in Britain.

T. latus and *T. scalaris* are common on the dog and ox respectively.

Philopteridæ.

Antennæ five-jointed; tarsi with two claws. Found on birds.

The principal genera of this large family are *Docophorus* (215 species), *Nirmus* (228 species), and *Lipeurus* (181 species).

D. communis has been recorded from nearly one hundred species of birds; *Nesiotinus demersus* is an interesting species found on the penguin, and *Eurymetopus taurus* is a parasite of the albatross.

Sub-Order II. *AMBLYCERA*

Antennæ concealed, often clubbed, four-jointed. Maxillary palpi four-jointed; mandibles horizontal. Suture between meso- and meta-thoracic segments usually visible. Testes, six. Egg-tubes three to five.

Gyropidæ.

Tarsi with one claw. Found exclusively on mammals.

There is only one genus—*Gyropus*—with seven species. Denny mentions two species, *G. ovalis and G. gracilis*, as British, both occurring on the guinea-pig.

Liotheidæ.

Tarsi with two claws.

The members of this family are bird-infesting with the exception of three small genera, viz. *Boopia*, with five species, found only on wombats, wallabies, and kangaroos; *Heterodoxus*, one species, found on wallabies; and *Latumcephalum*, one species, also a parasite of wallabies.

All the other species in this family are found on birds, the principal genera being *Menopon*, with 211 species, and *Colpocephalum*, with 137 species.

DERMAPTERA

Segments of the body imbricate. Biting mouth-parts; body flattened.

This order has been formed mainly to include the earwigs, formerly classed with *Orthoptera*.

The addition to it of *Hemimeridæ* is at least doubtful, but is rendered more plausible by the existence of *Arixenia*, a parasitic earwig.

The literature is referred to below.

Burr creates sub-orders, super-families, and six families of true earwigs (Forficulids), but they are here treated as a single family. If we accept these many families in this order, then we should have to accept many more in *Orthoptera*.

Forficulidæ (*Euplexoptera*).

Earwigs.

Elongate, slightly flattened, elytra truncate. Wings folded radially and transversely; many wingless. Abdomen long and terminated by two anal cerci formed as forceps. Free living.

Owing to a closer study of the relationships of insects, the earwigs have now been removed from the *Orthoptera*, where they formed the family *Forficulidæ*, and have been placed nearer the *Coleoptera* in a separate order.

The common earwig, *Forficula auricularia*, is a very well-known insect, which is regarded with more general loathing than interest. It received the common name of earwig owing to the superstition that it enters the human ear and travels thence into the brain. It has been stated that the name originates from the shape of the wing, which in some measure resembles a human ear, but it is scarcely possible that the insect should receive its popular name through an organ which is very rarely seen.

Earwigs are medium-sized insects, with running legs of moderate length, generally coloured in the sombre blacks and browns of nocturnal insects, although a few are brilliantly coloured. The forceps are characteristic of the order, but extremely variable. One or two mimic insects of other orders. They are common in Europe, but are said to be somewhat rare in other parts of the world. They inhabit both temperate and tropical regions, the species being more numerous in the latter.

The prothorax is free, usually rather square, and the thoracic segments generally are distinct, while each sternum on the thorax projects backwards so as to overlap the anterior part of the following segment. The abdomen is slightly broader than the thorax, is elongate and formed of the segments, which are fitted together by a complex imbrication which allows of great strength combined with flexibility. Each segment is formed of an upper and lower plate, which overlap one another at the sides, and are inserted far forward in the preceding segment. The visible segments are two less in the female than in the male, but segments eight and nine are small and practically absent. At the end of the abdomen are situated the remarkable forceps or anal cerci. They are often half as long as the whole body, but are in a few species extremely variable in the same sex and species, both in length and shape. They sometimes cross one another and assume the most remarkable shapes, being perhaps most variable in the male sex, and are always present in the apterous forms. That they are the true anal cerci is shown by the fact that a Ceylon species, of the genus *Dyscritina*, has anal cerci formed of many segments when in the young nymphal stage, but loses all but one segment, which forms the forceps, when it becomes adult. Their use is purely conjectural. They have been observed to be used as weapons of offence and defence, and

Fig. 38.—*Forficula auricularia* ♀. (× 2.)

it is thought that they may assist in the complicated business of folding the wings, but the real purpose remains a mystery. Between the forceps is a perpendicular plate known as the telson, the pygidium being a separate plate, which has the appearance of being the tenth dorsal sclerite bent downwards. On most earwigs there is a small fold on the tergite of the fourth segment or thereabouts, which contains a small opening connected to odoriferous glands. In a rudimentary state, earwigs show an attempt at union between the thorax and the first abdominal segment.

The mouth-parts are of the usual mandibulate structure, with fairly prominent maxillulæ in association with the hypopharynx. The labial and maxillary palpi are stated to be sensory, and there is a small apical segment on the palpi which seems characteristic of the order. The head, which is slightly flattened, carries large compound eyes, but no ocelli. The antennæ are about half the length of the body and filiform, almost moniliform. The number of antennal segments increases with age, there being from ten to fifty in the adult. The elytra are short, thick and leathery, and rarely cover more of the body than the portion below which the hind-legs are inserted. They meet in a straight line down the back. The wings are very large compared with the elytra, and fold in the complicated manner indicated above—a way of folding the wings used by no other insect. They project slightly from under the elytra, the portion which projects being harder than the rest and coloured to harmonize with the elytra. When expanded, which it rarely is, the wing is shaped like the human ear and is very delicate in texture. *Labia minor* flies freely, and can often be watched folding up its wings. The legs are inserted far apart, have small free coxæ and three tarsal joints, generally with no pulvillus. The spiracles are small and placed on the pleural membranes, making it impossible to see them unless the body is well stretched out. There are three pairs of thoracic and seven pairs of abdominal stigmata. The genital orifice has been observed to be double in some males. The forceps are generally larger in the male, which has nine visible ventral segments, while the female has seven.

The alimentary canal is not convoluted, and is provided with a crop and a gizzard. Salivary glands are present, and

there are thirty to forty Malpighian tubules. The tracheal system is small, with no dilatations, and there are three thoracic and six abdominal ganglia, of which the last is larger than the rest. The ovaries vary. The common earwig has only one tube on each side, while species of *Labidura* have five, terminating separately into the oviduct, which lies obliquely in the body cavity. The testes are a pair of curved bodies connected to a slender vas deferens. The oviducts open separately to the exterior, but a male has been recorded in which there was a double ejaculatory duct. It is interesting to note that the genital ducts of this order are mesodermal and not ectodermal in origin.

Little is known of the life-history in general, but that of the common earwig has recently been worked out in the United States. The eggs are round and white and are laid in batches of fifty to ninety in the ground or under some shelter. They are generally laid in the autumn, and the female remains with them and hibernates. It is stated by some authorities that the female tends the young nymphs, which hatch in the spring, but others deny this and say she has no further interest in her progeny after they have hatched. The young nymphs lie in a curved position in the egg and are provided with an egg-tooth for piercing the shell. When they just emerge they are white and could easily be confused with the *Thysanura* at first glance. They are similar to the adult, and in the apterous species are difficult to tell from the adult except by the chitin, which is much softer, and by the fact that the pincers are less developed and that the antennæ have fewer joints. It has been stated that they will collect under the mother like chickens under a hen, and they have also been observed to eat their mother's dead body. The imago is most active in damp weather, sometimes comes to light as in the case of *Labidura*, is nocturnal in habit and lies in concealment during the day. The food of earwigs consists of decaying vegetable matter, small insects and larvæ, and sometimes their own race. They devour pollen, sap and the petals and stamens of flowers. The nymphs of *F. auricularia* have two feeding periods in the United States, the first one occurring in spring and the second later in the summer. Their food at first consists of the tender shoots of clovers, grasses,

dahlia and other plants. Later on they feed on green shoots, blossoms and the bases of petals and stamens. These foods are presumably in addition to the ordinary mixed carnivorous and herbivorous diet.

Hibernation takes place in the autumn, the individuals consisting of young adult males which have developed too late for copulation, and females. All other males die after copulation has taken place. For the purpose of hibernation the adults often collect in large numbers. They are to be found in the ground or in sheltered places, such as under the bark of trees, in rotting vegetation, under stones—in fact anywhere where it is fairly damp. Many are found on the seashore, and *Anisolabis maritima* lives under seaweed in the United States. *Labia minor* can generally be found in the neighbourhood of manure heaps. The natural enemies are such insectivorous vertebrates as birds, frogs and toads, and also predatory beetles. There is a Tachinid parasite, and many are attacked by nematode worms of the genus *Mermis* and *Filaria*, which lives in the body cavities of adults and nymphs.

For a more extended study of the order the following works should be consulted: Perkins (1903); Kirby's Catalogue (1904); Burr (1914) and *Gen. Ins.* Fasc. 122 (1911); U.S. Dept. Agri. *Bull.* 566 (1917); Brindley (1918); Lucas, *British Orthoptera* (1920).

Seven species are indigenous to Britain and four species have been introduced. Known species number about 500, with a total of somewhere about double that number.

As a whole the economic importance of the *Dermaptera* may be said to be small, although in many cases they may be much less of an actual pest than is supposed. For instance, *Chelisoches melanocephalus* is commonly found in the bores made by boring caterpillars in sugar-cane, and may be acting as a check, while Perkins observed *Anisolabis annulipes* attacking the hopper *Perkinsiella saccharicida*. As pests they are confined to gardens, and in Europe, at any rate, are not to be counted at all serious. They are probably kept down by the natural enemies, and the ordinary gardener's method of inverted flower-pots filled with grass serves to check their damage on show flowers. In 1911, however, *F. auricularia* was noticed in some numbers in the gardens of large estates

at Newport, R.I., and by 1916 had become a serious pest on ornamental flowers. This was probably owing to the earwigs having been imported without all the natural enemies. Action was taken against them by spreading poisoned bait early in May to kill the young nymphs. A mixture of stale bread and Paris green, made into a thin paste with water, was scattered broadcast late in the evening. This appeared very effective and was not dangerous to song-birds owing to the large amount of other food available. After the nymphs had migrated to the blossoms, they were sprayed with a soap and nicotine sulphate solution. In England earwigs have been so abundant in camps and in houses as to constitute a real pest. Gardeners dislike them for their habit of collecting in soft-petalled flowers, such as dahlias, which they eat.

Arixeniidæ.

Parasites on bats. Eyes reduced; wingless. Mandibles flattened, not functional. Cerci long, not segmented.

A family formed by Jordan (1909) for insects found in the pouch of a Malayan bat. Included in *Dermaptera* by Burr in *Genera Insectorum*, Fasc. 122 (1911). Jordan refers to them as anatomically and morphologically a connecting link between the earwigs and *Hemimerus*, but "not in a phylogenetic sense." In general they resemble the wingless earwigs; and it is a possible point of view that they are a link to *Hemimerus*. Whatever place we give to *Hemimerus*, this apparently definite family are closely related, phylogenetically, to *Forficulidæ*. They are obviously of no economic importance: *Arixenia esau* Jord. is the known species.

Fig. 39.—*Arixenia esau*. (Simplified from Jordan.)

Hemimeridæ.

Small, blind and wingless insects, with long flexible cerci; found as parasites on the bodies of some African rodents.

In appearance the *Hemimeridæ* are something like very small Blattids, but are distinctly smaller than *Cimex*. They are exceedingly rare, and very little is known about them. As far as is known they are limited to parts of West and East Africa.

The body is somewhat flattened, the pronotum large, and the abdomen fairly broad, terminating in a pair of long one-segmented cerci. They are brown in colour. The structure of the pleura is not understood, but on the abdomen they are said to be similar to those found in *Forficulidæ*. The labrum is large, as are the mandibles, which are toothed on the inner edge. The maxillæ are well developed and are provided with five-jointed palpi. The most notable part of the structures which form the mouth is the Epipharynx-hypopharynx, which consists of a bilobed organ with an articulated appendage on each side, probably a palp. The legs have small coxæ, and are provided with three-jointed tarsi, two of these joints being pubescent below. The spiracles are difficult to see, but Hansen says there are ten pairs. The genital aperture is situated between segments eight and nine. Reproduction is viviparous, the young being said to be born six at a time, but it is more probable that they are born singly. The ovaries are stated to have eight egg-tubes each. Hansen has stated that the nymphs are connected with the walls of the material organs by a process from the neck, but no details of this have been ascertained. The nymphs are said to be similar to the adults, but with a simpler structure of the antennæ, which are long and filiform in the adult.

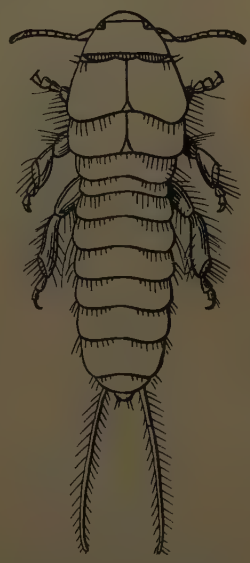


Fig. 40.—*Hemimerus Hanseni.*
(After Hansen.)

For the available information on these little known insects the following should be consulted: Saussure (1879), Hansen (1894), Bormans and Krauss (1900), Vosseler (1907), Carpenter (1909), Jordan (1909), Heymons (1912).

There are no British species, and the group is of no economic importance.

COLEOPTERA

Beetles.

Fore-wings (elytra) thickened, meeting in a straight line. Biting mouth-parts; second maxillæ fused.

This is a large and very well-known order. Its members are widely distributed throughout the world and are found in all situations. Many of them are of considerable economic importance and come a good deal under the notice of mankind.

Beetles are as a rule very easily recognizable, being different in appearance from the insects of any of the other Orders. They have, with few exceptions, a hard or leathery integument and two pairs of wings, the anterior pair usually being horny, forming a shield or covering for the posterior pair, which are membranous, and in most cases functional, folding, when not in use, beneath the elytra, as the anterior pair are called. The elytra in the majority of cases meet in a straight line down the centre of the back; but there are several species in which they become widely separated toward the apex. In some cases they are more or less truncate, as in the *Staphylinidæ* and *Pselaphidæ*.

The head is as a rule normal in shape and size, and is very mobile. There are, however, a number of species in which it is of unusual form, e.g. in the *Rhynchophora* it is produced in front to a greater or less degree, often forming a long, beak-like structure known as the rostrum, at the apex of which the mouth-parts are situated. The mouth-parts are of the predaceous or herbivorous biting type. There is a labrum or upper lip usually present, varying in size and entirely wanting in the *Curculionidæ*. The mandibles vary according to the food-habits of the beetles. The herbivorous species have short, broad, blunt mandibles, well adapted for the kind of work they have to do. Carnivorous beetles have longer mandibles, sharply pointed, and sometimes with a cutting edge. With one exception the mandibles move horizontally: the exception is that of the genus *Balaninus* of the *Curculiondæ*,

in which the mandibles move vertically. There are a pair of maxillæ present, furnished with three- or four-jointed palpi. The palpi are rarely five-jointed. The lower lip or labium carries three- or two-jointed palpi which are in some cases setiform. The compound eyes vary much in shape, some being oblong, kidney-shaped, or round, others divided by a ridge, or strongly emarginate. The number of facets vary considerably. In some cave-dwelling species eyes are absent. Ocelli, although the usual organs of vision in the larvæ, are very seldom pre-

FIG. 41.—Types of Antennæ.
1. Filiform—Carabid. 2. Serrate—Elaterid. 3. Lamellate—Lucanid. 4. Clavate—Staphylinid. 5. Geniculate—Curculionid.

sent in adult beetles. The genus *Homolium* of the *Staphylinidæ* and some of the Dermestids possess a frontal ocellus.

The antennæ, also, are very variable, showing great diversity as to form, length, number of joints, and, in a less degree, position. The majority of the beetles have eleven-jointed antennæ placed either in front of, or between, the eyes. As regards form they may be filiform or simple, moniliform, clavate, flabellate, serrate, lamellate, and lamellate with the club formed of movable, leaf-like segments. (Figs 41, 42).

The head is usually broadly united to the thorax; but in

some cases there is a distinct neck. The thorax is composed of three portions; the prothorax, the mesothorax and the metathorax; the upper portions being the pro-, meso-, and metanotum and the lower portions the pro-, meso-, and metasternum. The pronotum is never joined to the mesonotum. The metanotum is covered by the elytra, while only a small part of the mesonotum is visible, this visible portion being called the scutellum. The pronotum is plainly visible. The elytra are appended to the mesonotum and the wings to the metanotum. The anterior pair of legs are borne by the prosternum, the intermediate pair by the mesosternum, and the posterior pair by the metasternum. The abdomen is made up of a varied number of segments, usually five or six being visible on the ventral surface; on the dorsum, covered as a rule by the elytra, seven, eight, or even nine segments are visible. The elytra in the majority of cases completely cover the abdomen; but in some species, as mentioned above, they are very truncate: in some other forms they leave the apex of the abdomen exposed. Wings in many cases are large and functional; in some forms, however, they are very rudimentary or totally absent. When not in use the large, functioning wings are neatly and intricately folded beneath the elytra.

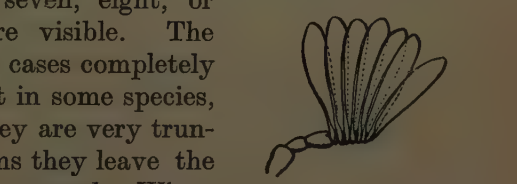


Fig. 42.—Antenna of Cockchafer (*Melolontha vulgaris*) ♂. (× 6.)

The legs vary as to length, size, and shape, being adapted to the habits of their possessors. They may be formed for digging, as in the *Scarabæidæ*, or for swimming, as in the *Dytiscidæ*: beetles like the Cicindelids have the long, slender, running type of leg; others, like the Halticids, have the hind-femora thickened and formed for jumping. The number of tarsal joints vary, but there are never more than five. The coxæ, which join the legs to the body, fit into sockets, called the coxal cavities. The cavities of the anterior coxæ, if placed entirely within the prosternum, are said to be closed behind; but if placed on the juncture of the prosternum and mesosternum, are said to be open behind. In some species there is a small trochantin attached to the coxæ of the anterior and intermediate pairs of legs.

As regards the internal structure, the alimentary canal is of more or less normal character. The pharynx, opening from the mouth, is followed by the œsophagus, which passes as a tube of varying size and length through the thoracic cavity. A crop is present in most of the adult beetles and also in certain of the larvæ. Following the crop is the proventriculus, of which the inner surface is provided with horny ridges or spine-like teeth : it is well developed in all carnivorous and wood-

FIG. 43.—*Coleopterous tarsi.* (× 25.)
1. Carabid—simple type. 2. Curculionid—Rhynchophorous type. 3. Chrysomelid—Phytophagous type. 4. Coccinelid.

feeding beetles, but is not present throughout the whole order. The mid-intestine, or chylific stomach, is somewhat variable, being in some cases very elongate and coiled : in carnivorous species it bears elongate, pouch-like structures. The *Lamellicornia* and the *Phytophaga* have a more simple form of mid-intestine, although it varies in length, being very long in *Lamellicornia*, and short and small in the Cerambycids. At the junction of the stomach and the intestine proper are the

Malpighian tubules, which number either four or six. The intestine, or small intestine, is somewhat variable, being long in some species (*Necrophagus* and *Dytiscus*), and short and slender in others (*Carabidæ* and *Chrysomelidæ*). The colon, or anterior portion of the rectum, is in some species (*Dytiscus*, *Necrophagus*) developed into a curious, bladder-like cæcum. The rectum, which is sometimes larger than the colon, is provided with structures, which, for want of a better term, are known as rectal glands. The anus is often furnished with glands of a repugnatorial nature, which secrete an offensive and corrosive fluid. Many species of Carabids possess this means of defence, especially the genus *Brachinus*, containing the Bombardier Beetles, which are able to emit a bluish vapour together with an explosion. Species of other families, also, have the power of ejecting fluids in some form or other.

Salivary glands are usually present, varying in number and character. Silk glands, although not usually present in *Coleoptera*, are found in some Chrysomelids and Curculionids, situated near the œsophagus.

The nervous system consists of a number of ganglia or nerve centres united with each other by one or two nerve cords. The supra-œsophageal and the sub-œsophageal ganglia of the head are merged into one main ganglion. The ventral ganglia vary in number : e.g. the *Lucanidæ*, which have six or seven ganglia situated in the abdomen, and the *Scarabæidæ*, in which all the ventral ganglia are concentrated in the thorax.

The tracheal system is well developed, in some large forms with air-sacs. Usually there are spiracles on all the segments with the exception of the head and last segment of the abdomen. In many aquatic larvæ gills are present in the form of lateral abdominal processes.

With regard to the reproductive system, the female organs consist of two sets of ovaries, each containing a varying number of tubes ; an oviduct with accessory glands, a copulatory pouch with spermatheca and its accessory gland and the vagina to the copulatory pouch. In the *Adephaga* the ovaries are of the meroistic type, whereas the members of the other divisions have ovaries of the holoistic type. The male organs consist of the testes, vas deferens, ejaculatory duct, seminal vesicle, accessory glands and ædeagus or penis. In the *Adephaga* the testes are

simple, coiled tubes, but in other groups they consist of a number of little sacs opening into a main tube ; testes of this form are sometimes enclosed in a sort of capsule. In some families there are more than one pair of accessory glands. The vasa deferentia vary greatly in length, and in the case of *Cetonia* are extremely long.

Besides the compound eyes and ocelli, already mentioned, there are other sense organs present in the insects of this order. The organs of smell have been proved to be situated in the antennæ, in the form of minute pits connected with nerves. The antennæ are also claimed to be the seat of the organs of hearing. Taste organs are said to be situated on the epipharynx, either as hair-like setæ or minute pits. The antennæ are tactile organs, and sensitive, tactile setæ are found on various parts of the head and body. Many beetles have the power of stridulating, and organs for this process are found on various parts of the body and legs. Gahan (1900) has written an excellent paper on the stridulating organs.

There is a wide range of colouring in the *Coleoptera*. Many beetles are very beautiful, with brilliant metallic colours ; others are vividly marked with sharply contrasting colours, giving a warning note to those birds and insects which seek to prey upon them, for many are possessed of extremely unpleasant, acrid flavours. Some species, which are in themselves harmless, successfully mimic the colouring, and sometimes the actions, of insects which do have some defensive properties. Protective resemblance is in this order carried out to a high degree of excellence, there being numerous instances of this among the tree-living beetles like the Longicorns and some of the *Rhynchophora*, many of which exactly resemble the grey, lichen-covered branches of the trees on which they rest. The habit of folding the limbs and feigning death is adopted by some species in the hope of escaping the attentions of their enemies.

Beetles have a complete metamorphosis. The eggs are of two types : soft, oval eggs and harder eggs of varied shape. None of them are sculptured like those of the *Lepidoptera*. The soft eggs are the type laid in concealment, while the harder eggs are usually laid in the open. The larvæ are of two types : the Campodeiform and the Eruciform or grub-like larvæ, like

those of the Scarabæids; the Campodeiform larvæ are the active type, such as those of the Carabids and the Staphylinids. There are modifications of these two forms. The pupæ are usually soft and have the appendages more or less free. The larval habits are very diverse and where known are mentioned under their respective families. The length of the life-history varies, some species having several broods a year, while others take three or four years to attain the adult stage.

The adults range in size from the minute to some of the largest insects known. Their habits are very varied: the

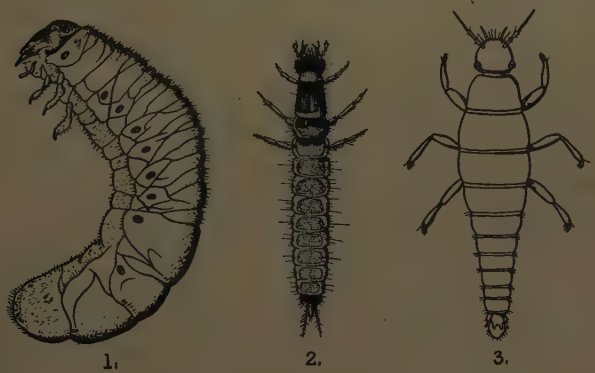


FIG. 44.—Larvæ.

1. *Oryctes rhinoceros* (after Lefroy). 2. Carabid larva (L.N.S.). 3. Triungulin larva of *Sitaris muralis* (after Riley and Packard).

majority are terrestrial; but a considerable number are aquatic. The terrestrial forms are found in situations too numerous to mention except under their particular families. Many are predaceous, many herbivorous; while others live on decaying animal and vegetable matter, acting as scavengers. There is no real social life and but few parasitic forms.

Both larval and adult beetles are preyed upon by birds, monkeys, and other small mammals. Insects of other orders also seek them as food, and many predatory beetles do not hesitate to devour their own kind.

The classification of the Coleoptera since the time of Linnæus has undergone many changes, some of which were very clearly needed. The classification used in the following work

is the one adopted by Fowler, and is a combination of the systems formed by Ganglbauer and Sharp. The hundred and three families are divided into three sub-orders :—

1. *ADEPHAGA.*

2. *POLYCERATA* (Polymorpha or Polyphaga), which is split into six divisions :—

1. *Staphylinoidea.*
2. *Clavicornia.*
3. *Serricornia.*
4. *Heteromera.*
5. *Phytophaga.*
6. *Rhynchophora.*

3. *LAMELLICORNIA.*

For authorities and catalogues the student should consult the numerous monographs in *Genera Insectorum*, references to which are given under the various families. References to the families listed in the Berlin Catalogue, edited by Schenklin, 1910, are also quoted. Descriptions of the British species will be found in Fowler, *British Coleoptera* (i–v, 1887–1891) and *Supplement* (Fowler and Donnisthorpe, vi, 1913) : reference is made to this work in each family below ; other volumes used include *Indian Insect Life* (1909), Sharp, *Cambridge Natural History*, vol. ii (1899) and Fowler, *Introduction to Coleoptera and Fauna of British India* (1912).

Regarding economic importance, the beetles undoubtedly rank high in this respect ; their vast numbers, their wide distribution, and the diversity of their habits and situations cause them to be a serious menace to mankind in his work of making the earth fruitful.

Sub-Order I. *ADEPHAGA*

Tarsi five-jointed. Antennæ filiform.

Ten families are included in this sub-order, all with the characters quoted above. These families contain active, predatory insects, and there are but few of economic importance.

Cicindelidæ.

Tiger Beetles.

Clypeus extending laterally beyond base of antennæ; maxillæ terminating in an articulated hook.

This family is well represented in both temperate and tropical regions.

The members of this family are usually recognizable by their general form, which distinguishes them from the *Carabidæ*, their near allies. They are, on an average, about an inch long, and are as a rule brightly coloured; black, green, or brown, with dots or splashes of white, being typical of them.

The head, which is well defined, bears mouth-parts of the predaceous type, consisting of long, curved mandibles, well adapted for seizing and holding their prey, and well-developed labium and maxillæ. The antennæ are simple and of medium length, and the eyes are prominent. The legs are long, finely spined, and adapted for running. The sexes are recognizable by the fact that the female has seven visible ventral abdominal segments, while the male has only six.

The period covered by the life-history varies according to species, some taking two and others three years: that of *Cicindela campestris*, a well-known British species, is three years. A few forms are known in which the larvæ spend their existence in the stems of trees and bushes; but the great majority prefer damp soil, particularly sand with a small percentage of clay. About fifty eggs are laid separately in little pits formed by the ovipositor of the female. The eggs are, in shape, an elongated oval, and of a clear cream colour. The period of incubation is from ten to fourteen days. There are three larval stages, covering a period varying from ten to twenty-one months. Hibernation as larvæ or adults is the general rule. The larvæ enlarge the pits as they grow and spend their whole time in them, waiting for unwary insects to pass within reach. They support themselves in their burrows by means of their legs and a projection on the dorsal surface of the fifth abdominal segment. Pupation takes place in the soil, in a little chamber hollowed out from the side of the burrow.

An account of the "Life-Histories and Larval Habits of the Tiger Beetles" has been written by Shelford, 1908. Criddle (1910) has done some work on this family.

The British species, which number four, belong to the genus *Cicindela* (Fowler).

There is only one instance of the *Cicindelidæ* being of any economic importance, and that is in the East Indies, where the larvæ of some of the species of the genus *Collyris* burrow in the stems of coffee plants. A species of *Tricondylea* is also injurious to coffee. The remainder are carnivorous in both stages and possibly beneficial.

Carabidæ.

Carnivorous ground beetles.

The clypeus not extending laterally beyond base of antennæ. Maxillæ not hooked.

This is a very large family, having a wide range in both temperate and tropical regions.

They are from small to moderate size and are usually of sombre appearance, although there are a few species having a more vivid coloration.

The head is, as a rule, narrower than the thorax : the filiform antennæ are of moderate length. The mouth-parts are conspicuous and strongly predaceous. The eyes are large and in some cases prominent. Wings are absent in some species, the elytra then being soldered together. The legs are well-developd and fairly long, except in a few instances when they are used for digging, they then being shorter and more stoutly built. The males have the basal tarsal joints of the fore-legs expandcd.

Up to the present little has been found out as to the complete life-history. In the case of *Anthia sexguttata*, however, the eggs are known to be about a quarter of an inch in length, oval, white, and soft. The larvæ are slender, with large heads and long mandibles. There are three pairs of moderately long thoracic legs. The body gradually tapers and terminates in a pair of cerci and an anal tube. They are of a dull colour and are very seldom seen, living, as they do, in concealment most

of the day. Pupation takes place in the soil. The life of the adult is considered to be long, the beetles hibernating in the earth, under stones or other places which afford shelter. Some species are diurnal and others nocturnal in their habits. The majority of them possess glands opening just above the anus, which emit an evil-smelling liquid when the beetle is alarmed by the approach of an enemy: in a few species the liquid, when liberated, goes off with a small report, thus being an admirable means of defence. With very few exceptions the Carabidæ are carnivorous in both larval and adult stages, living on caterpillars and many other forms of insect life. It is difficult to say where these beetles are not to be found, hill and plain, forest and pasture, all having their quota of them.

The various sub-families of the *Carabidæ* have been monographed in the *Genera Insectorum*, by E. Rousseau in fascicules 38 (1905), 40 (1906), 83, 84, 85, 86 (1908) and by Dupuis, fascicules 116, 117, 123 (1911), 126, 134 (1912), 145, 146, 147 (1913).

Horn has done much towards the classification of this family (1881), and *Gen. Ins.* Fasc. 82 (1908, 1910, 1915).

The British representatives number over 300 species (Fowler).

The family as a whole can be said to be beneficial, their carnivorous habits helping to keep in check the superfluous insect life. There are, however, a few cases in which they are injurious, young wheat sometimes being attacked and also strawberries.

Species of *Zabrus* and *Clivina* are injurious to wheat; *Harpalus* and *Pterostichus* attack strawberries.

Amphizoidæ.

Antennæ inserted just in front of the eyes. Pronotum short and narrow; elytra ovate. Legs not formed for swimming.

A very small aquatic family of one genus, comprising only three species, two of which are found in Western North America and one in Eastern Tibet.

They are little over half an inch in length and are dingy in appearance.

Their mouth-parts resemble those of certain of the Carabids.

The legs are feeble, and not, as might be expected, adapted for swimming.

The larvæ are also similar to those of the genus *Carabus*, the abdomen terminating in a pair of cerci, but not having an anal tube. The adults as well as the larvæ spend their lives in cold, rapid streams, clinging to stones, etc., they being very poor swimmers. Both larvæ and adults are presumably carnivorous.

Sharp (1882) has written on this family.

Pelobiidæ (*Hygrobiidæ*).

Head not sunk into prothorax. Antennæ bare. Anterior coxæ conical, tibiæ and tarsi provided with swimming hairs.

This is a very small family of one genus, two members of which are found in Australia, one in Chinese Tibet, and one in Britain.

In general form they resemble the *Amphizoidæ*, but are more convex and have the head more prominent.

The mouth-parts are of the predaceous type; the head is free, with prominent eyes. The moderately long legs are fringed with hairs which assist in swimming, while in the male the anterior and intermediate tibiæ are dilated.

The larvæ are of rather curious form, having a large head bearing predaceous mouth-parts, and a sharply tapering body, the eighth abdominal segment ending in three long processes. The adult insect, which is found, like the larva, in ponds and ditches, has the power of stridulating; the sound, according to Darwin, being produced by the tip of the abdomen rubbing on a file-like structure on the under-side of the elytra.

The species are listed by Zimmermann in the Berlin Catalogue. The one British species is *Pelobius tardus* (Fowler), usually sold in Covent Garden and elsewhere under the name "Squeaker."

Haliplidæ.

Antennæ ten-jointed, inserted near eyes. Hind coxæ extend into two broad plates covering first three sternites.

This is a small family comprising about 100 species, the majority of which are found in temperate regions.

They are all of small size, never exceeding 5 mm. in length, of an oval shape and usually of a dark colour.

Their mandibles are grooved, enabling them to suck their prey. The plate-like form of the hind coxæ make a good character for recognizing the members of this family. The males have the three basal tarsal joints of the anterior legs slightly dilated.

The larvæ are of peculiar form, having many fleshy appendages attached to various parts of their body. In habit they are somewhat sluggish and cling to weeds, etc., in streams and ponds. The adult insect is also found in ponds and running water, and by the type of its mandibles is presumably carnivorous.

The species are listed by Zimmermann in the Berlin Catalogue.

There are thirteen British species (Fowler).

Dytiscidæ.

Posterior coxæ enlarged, contiguous at inner margins. Hind-legs formed for swimming. Males with the three basal joints of fore tarsi dilated.

About 2,000 species are contained in this family. They have a wide distribution, but are more abundant in temperate than in tropical regions. Their colouring is usually some unobtrusive shade of brown or blackish bronze; but there are a few tropical species more brightly coloured. They vary in size from quite small insects to fine, broad species over an inch in length. All are compactly built and oval in shape.

Fig. 45.—*Dytiscus marginalis* (nat. size).

The head is broad, and closely fits the thorax. The mouth-parts are of the carnivorous biting type. The eyes are large, the antennæ filiform and of moderate length. The elytra, which closely join the thorax, cover the abdomen completely. Functional wings are present in all species. The anterior pair of legs are of moderate length, and in the males have the

three basal joints of the tarsi dilated to form a sucker-like pad. The posterior legs are long and adapted for swimming, with the tarsi somewhat flattened and ciliated at the edges. The elytra of the females of some species have a series of deep grooves down two-thirds of their length. An unpleasant fluid is emitted from the anus and the articulation of the head when these beetles are seized.

Eggs are laid in the water on the leaves of aquatic plants. The resulting larvæ are elongate, with a large, flat head and a narrow, tapering body, terminated by two hairy processes. There are three pairs of long, swimming legs. The air supply is obtained by means of two spiracles at the apex of the abdomen. The mandibles are long, curved and hollow, a device which enables these larvæ to grasp and suck the juices of their victims. The larvæ leave the water to pupate, making a cocoon in the mud at the water's edge. Both larvæ and adults are carnivorous, the larvæ fiercely so. The adults often take to flight on hot days. They are found in both stagnant and running water, but more usually the former.

There is an excellent monograph by Sharp (1880–2) on this family. Miall, in his *Aquatic Insects*, gives an account of *Dytiscus marginalis*, a big British species.

Zimmermann lists the species in the Berlin Catalogue.

There are 106 British species.

Gyrinidæ.

Whirligig beetles.

Antennæ short and thick; eyes divided. Hind coxæ fixed and posterior legs formed into paddles.

These beetles are widely distributed throughout the world.

A family of small beetles, easily recognizable from their habit of swimming about in intricate curves and circles on the surface of fresh water. They are usually shiny and black in colour.

The head, which is large, bears very short, inconspicuous antennæ. The eyes are divided, so that when the beetle is swimming on the water one portion of the eye is above while the other is under the surface. The middle and hind legs are

hort and paddle-like in form, enabling the beetle to perform ts gyrations. The males have the anterior tarsi dilated. The emales are often slightly larger and less shiny.

Eggs are laid on aquatic plants. The larvæ are aquatic, nd are furnished with lateral gill processes on each of their bdominal segments. Pupation takes place in flimsy cocoons, vhich are usually attached to aquatic plants, clear of the water. The adult spends most of its time on the surface of either still r running water, only diving below the surface on the approach f danger. They are attracted by light, when they will leave he water by flight. Both larvæ and adults are considered to e carnivorous.

The family has been monographed by Regimbart in *Genera Insectorum*, Fasc. 1 (1902), and also by Sharp. There are leven British species (Fowler).

Paussidæ.

Antennæ of abnormal and varied forms. Elytra truncate, ygidium usually exposed.

A moderately large family of about 300 species, well repre- ented in both tropical and sub-tropical countries. One species s found in the south of France.

Small beetles, rarely exceeding half an inch in length, usually lack in colour, with deep-blood-red markings. They are asily recognizable by the extraordinary forms of the antennæ.

The mouth-parts are rather small, with short, curved mandibles. The antennæ are extremely variable, both as to orm and the number of joints, anything from two to eleven, ome of which are often expanded into a leaf- or blade-like form. The wings are well developed. The legs are stoutly built and ometimes have the femora and tibiæ much expanded.

The larvæ, which are carnivorous, and found in ants' nests, much resemble those of certain *Carabids*. The adults in nearly ll cases are also myrmecophilous, chiefly inhabiting the nests f terrestrial ants, although some have been found in the nests f tree-infesting ants. It has been suggested that these beetles ecrete some substance which is attractive to the ants. They lso have the power of discharging, with a slight explosion, a

caustic fluid. They are much given to flying at night and are attracted by light.

The family has been monographed by Desneux in *Genera Insectorum*, Fasc. 35 (1905). Raffray, 1887, and Gestro, 1901, have also written on the family. Gestro lists the species in the Berlin Catalogue.

Rhysodidæ.

Head with a slender neck. Antennæ eleven-jointed. Hind coxæ widely separated. Tibial spurs oblong, double on anterior, single on middle and hind legs.

This family is comprised of only a few species, but is widely distributed, being found in both temperate and tropical regions.

In general appearance they somewhat resemble some species of Carabids and are elongate. In colour they are either black or brown.

The head, which is joined to the thorax by a distinct neck, bears mouth-parts which are entirely covered by a large mentum. There are six visible ventral segments. The legs are short, the anterior tibiæ have a pair of curved spines at the apex, while the middle and posterior tibiæ have only one apical spine. Little is known of the life-history. They are found under the bark of trees.

The species are described by Gestro in the Berlin *Catalogus Coleopterorum*.

There are no British species.

Cupedidæ.

Elongate. Abdomen with five visible sternites. Pronotum separated by sutures from pleuræ of thorax. Metasternum with cross-suture before hind margin. Elytra with lattice-like sculpture, body covered with grey scales.

A small family, the few species of which are found in the two Americas, the Philippine Islands, one in Japan, Burma, and Eastern Siberia, and one in Australia.

They are elongate insects, bearing some resemblance to the

Telephoridæ in general appearance. They are dull greyish brown in colour.

The head is small, with prominent eyes and long, stout, tapering antennæ. The elytra cover the abdomen and have a lattice-like appearance due to rows of large, square punctures. The legs are short and slender.

Little is known of their life-history. Some species frequent old, timber-built houses, but whether as wood-feeders or as parasites of other wood-borers is not definitely known.

The family has been worked on by Kolbe (*Zeitsch. Wiss. Insectenbiol.*, 1908) and Lameere (*Ann. Soc. Ent. Belge*, 1900). Gestro lists the species in the Berlin Catalogue.

Sub-Order II. *POLYCERATA* (*Polymorpha*, Sharp)

Antennæ usually clubbed or serrate. Number of tarsal joints varied.

This sub-order contains eighty-nine families, many of them of great importance.

(*a*) STAPHYLINOIDEA

Venation without cross-veins or loop. Antennæ simple.

Staphylinidæ.

Rove beetles.

Antennæ variable. Tarsi three- to five-jointed. Elytra truncate, only covering base of abdomen, which is flexible, with ten tergites and at least seven visible sternites.

A very large family, of universal range.

Its members are slender and elongate in shape and vary much in size, from the minute to about an inch in length. They are usually sombre in appearance, being black or a dull brown; but there are a few species which show a brighter coloration.

The mouth-parts are conspicuous, with stout biting mandibles. The antennæ may be ten- or eleven-jointed, filiform or clubbed. The eyes are not as a rule conspicuous, and in a few cases may be absent, but there are a number of species in

which they are very prominent, especially in the genus *Stenus*. The legs are of the active, running type. In some cases the abdomen terminates in two short style-like processes. The integument of these beetles is weaker and softer than is usually the rule in this order of insects. The wings are large, and when not in use are folded away under the short elytra.

The larvæ are in form not unlike the adults, with the addition of a pair of anal cerci and an anal tube. They have many of the characteristics of the Carabid and Dytiscid larvæ, being very active and rapacious. Some are predaceous on other insects, some feed on decaying animal and vegetable matter, while a few live on pollen and sap of plants. The pupæ in some cases are covered with a sort of gummy secretion which fixes the parts together, thus making a form of obtect pupa. The adults are found in many situations, but particularly where there is an accumulation of rubbish, or in dead birds and animals. Their food habits are much the same as those of the larvæ. They usually feed at night, spending the daytime in places of concealment. Some species are found in the nests of ants, where it is supposed they secrete a fluid attractive to the ants, and perhaps act as scavengers. The assuming of a menacing attitude is practised by a few members of this family, especially by the well-known "Devils' Coach-horse" (*Ocypus olens*), of this country, who, on the approach of danger, stands with widely opened jaws and the long, flexible abdomen curving upwards. A number of species give out an unpleasant odour when disturbed.

Fig. 46.—*Ocypus olens* (*Staphylinidæ*) (nat. size).

Bernhauser and Schubert have listed the species in the Berlin Catalogue.

Two sub-families have been monographed by Fenyas in *Genera Insectorum*, Fasc. 173A (1918).

There are over 800 British species (Fowler).

None are known to be directly injurious, and the family as a whole can be considered generally beneficial, owing to their predaceous habits and work as scavengers.

Pselaphidæ.

Small. Maxillary palpi large. Tarsi three-jointed. Elytra truncate. Five ventral abdominal segments. Myrmecophilous.

A fairly large family, well distributed about the world. They are very small beetles of dull colouring, usually brown.

The antennæ are of curious form, much subject to variation, and in some species the number of joints are reduced to even one. The tarsal joints are also reduced in number in some species.

Little is known of the life-history; but in one case in which the larva is known, it is said to resemble somewhat those of the *Staphylinidæ*.

The great majority of the species live in the nests of ants, where it is believed they secrete, from little pubescent patches distributed on various parts of their bodies, a peculiar substance that is attractive to the ants. Other species are found in moss, dead leaves or matter of a similar nature, where they feed on mites, etc.

The family has been monographed by A. Raffray in *Genera Insectorum*, Fasc. 64 (1908), and *Ann. Soc. Ent. France*, 1903–4.

There are about thirty-four British species (Fowler). They are not of any economic importance.

Gnostidæ.

Very small. Antennæ three-jointed. Tarsi five-jointed. Elytra cover the abdomen; three apparent sternites.

Only two species are contained in this family, and up to the present they have only been found in Brazil. Beyond the fact of their inhabiting the nests of the Cremastogaster ants, little is known about them. Westwood, *Trans. Entom. Soc. London* (N.S.), III, 1855.

Scydmænidæ.

Very small. Antennæ expanding apically. Tarsi five-jointed. Anterior coxæ contiguous, posterior coxæ separate, femora usually thickened. Six visible ventral segments. Eyes coarsely granulated.

A family of about 1,200 species, widely distributed throughout the world. They are very small beetles of a dull brown colour, and somewhat hairy.

The mouth-parts are of the predaceous type, the mandibles in some species being long and sickle-shaped. The elytra, which in the great majority cover the entire abdomen, in some cases leave the pygidium exposed.

Little is known of the life-history. The adults are found in moss, dead leaves, and matter of a similar nature, where it is presumed they are predaceous on such forms of life as the Acari. Csiki lists the species in the Berlin Catalogue. There are about twenty-four British species (Fowler).

Silphidæ.

Burying beetles.

Size variable, 1½–30 mm. long. Antennæ usually clubbed. Tarsi four- to five-jointed, anterior coxæ conical and contiguous. Eyes finely granulated. Apex of abdomen often exposed, five to six sternites, free.

Found in both tropical and temperate regions, but the greater number in the latter zone. Europe, North America, New Zealand, South Australia, and Tasmania.

A family of great variability both in point of size and form. The majority are small, not exceeding half an inch in length; but there are quite a number of an inch and over. They are usually of sombre appearance, but gaudy colouring, particularly orange and black, predominates in some species.

The mouth-parts are conspicuous, with strong mandibles. The head is capable of being bent down and hidden by the big thoracic plate. The legs are moderately long and stoutly built, especially in the genus *Necrophorus*.

Little is known of the larvæ of the smaller species, but those of the larger are flat and somewhat tapering. The larvæ of the genus *Necrophorus* bear spiny plates on the back of the body. A pair of cerci are usually present on the ninth abdominal segment. Some, especially those of the genus *Silpha*, are very active, and possibly predaceous, snails in particular being attacked. The larval food generally is decomposing animal or vegetable matter. The adults of the genus *Necrophorus* are well known as "Burying beetles," owing to their habit of excavating beneath the dead bodies of small mammals or birds, which gradually sink into the ground, where they are devoured by their buriers. Occasionally Silphids may be found in the nests of birds, but as a generality the ground is their habitat. The family has been classified by Dr. Horn, *Trans. Amer. Entom. Soc.* VIII, 1880. The British species number about 104 (Fowler).

A few species are more or less of economic importance, damage being done by the larvæ and adults to the leafage of certain crops, such as beet, cereals, spinach, and potatoes. The genera concerned are *Silpha* and *Bathysia*.

Clambidæ.

Minute, convex, hemispherical. Antennæ eight- to ten-jointed, with two-jointed club. Tarsi four-jointed. Head very large; maxillæ with two long lobes. Wings partly ciliate. Five to seven free sternites.

A family of near relationship to the *Silphidæ*. The majority of its species are found in Europe and North America; Ceylon and the Canary Islands have one representative each. They are very small, round, and convex, and are generally dull in colour.

The head is large and bears clubbed antennæ and maxillæ which have two long lobes. The wings are more or less ciliate. The number of visible sternites varies from five to seven. The larvæ are elongate, narrowing towards each extremity. These beetles live under bark or in decaying vegetable matter. There are four British species (Fowler).

Leptinidæ.

Small. Antennæ long and filiform. Eyes wanting or rudimentary. Tarsi five-jointed. Elytra covering abdomen.

A small family of only two genera, numbering three or four species altogether, and found in Europe and North America. They are small and dull of colour.

These beetles resemble in a general way some of the smaller Silphids; but their filiform antennæ are much longer, and they have a very short metasternum. They are usually blind, or the eyes, if present, are extremely rudimentary. The larvæ are unknown.

The European species is found in dead leaves, rotting wood, birds' nests, and are also said to live parasitically on the bodies of small mammals. The North American species have been found on the bodies of beavers. There is one British species, *Leptinus testaceus* (Fowler).

Trichopterygidæ.

Minute. Antennæ with a three-jointed club. Elytra abbreviated or complete. Wings fringed with hair. Tarsi three-jointed.

A family of wide distribution, but most numerous in the tropics. Some of the smallest known beetles are contained in this family; the smallest members are ¼ mm., and the largest rarely exceed 1 mm. They are obscurely coloured. The antennæ are clubbed and the maxillæ are tri-lobed. The elytra, according to species, may or may not cover the abdomen. The wings are remarkable in being very narrow and fringed on both edges with long fine hairs.

The larvæ are elongate, with large heads and eyes, and have the apex of the abdomen furnished with a pair of appendages. The adults are found in rubbish, among leaves, under bark or in rotten wood.

The family has been monographed by Dr. Matthews, London, 1892 and 1900, and listed by Csiki in the Berlin Catalogue. There are eighty-five British species (Fowler).

Hydroscaphidæ.

Minute. Aquatic. Antennæ eight-jointed. Tarsi three-jointed. Abdomen long and narrow. Wings deeply fringed with hairs.

A family comprising only four or five species, found in North America and Southern Europe.

In size not exceeding two millimetres. Obscure in colour. Their general characters resemble those of the *Trichopterygidæ*.

They are found in running water.

Monographed by Dr. Matthews, London, 1876.

Sphæriidæ.

Minute, hemispherical. Head and eyes large, antennæ short, eleven-jointed, clubbed. Wings large, deeply ciliated. Tarsi three-jointed. Three visible ventral segments.

A family of one genus of very few species, found in Europe and California.

They are very small insects, rarely exceeding 1 mm. in length. They are round and convex and somewhat shining.

The head and eyes are large; the maxillæ have only one lobe. The wings, which are larger than in the preceding family, have a fringe of long hairs. There are only three visible ventral segments.

They are usually found on mud or under stones in damp places. Dr. Matthews has written on the family. There is only one British species (Fowler).

Corylophidæ.

Minute. Antennæ eight- to eleven-jointed, loosely clubbed. Palpi with second joint much dilated. Tarsi four-jointed, third joint minute and concealed. Six free ventral segments.

A family of about 200 species, with representatives in all parts of the world. They are very small insects, usually of rounded form, but are more oval in some cases. They are

obscurely coloured in black or brown. In general appearance they resemble some of the smaller members of the *Silphidæ*. With the exception of one genus, the *Aphanocephalus*, the wings are fringed with hair. The palpi are remarkable in having the second joint much dilated. Both larvæ and adults are found in decaying vegetable matter and are believed to be predaceous.

The family has been worked on by Dr. Matthews, and listed by Csiki in the Berlin Catalogue. There are twelve British species (Fowler).

Phænocephalidæ.

Minute. Antennæ eleven-jointed, last three joints forming an elongate club. Head sessile, deflexed. Tarsi four-jointed, basal three bi-lobed, of equal length.

A family of one species, only found in Japan. In general appearance it seems to have some affinity to the *Corylophidæ* and *Trichopterygidæ*. The head, which bears clubbed antennæ, is large, broad, and is bent downwards. Nothing is known as to the habits or earlier stages.

Pseudocorylophidæ.

Minute. Antennæ eleven-jointed, apparently nine-jointed, the last three forming a solid club. Tarsi three-jointed, coxæ rounded and widely separated. Head retractile. Wings ample, broadest at the base, with distinct veins.

A family comprising thirty species contained in one genus. Some species occur in Penang, China, and Japan, and one in Brazil.

They bear relationship in various ways to the *Coccinellidæ*, *Trichopterygidæ*, and *Silphidæ*. They are very small and have a large retractile head and three-lobed maxillæ. The antennæ are short and bear a solid club. The wings are large, with quite distinct veins. The tarsi are three-jointed. The life-history is not known.

The species have been listed by Csiki in the Berlin Catalogue.

Scaphidiidæ.

Antennæ ten- to eleven-jointed, expanding apically. Legs long and slender, tarsi three-jointed. Elytra truncate. Abdomen with six to seven visible ventral segments, the basal one large.

A family of about 200 species, widely distributed in both temperate and tropical regions. They are small and bluntly ovate. Some species are brightly coloured, while others are of sombre appearance.

The head is of moderate size with the eyes prominent. The pronotum, which closely fits the elytra as in the *Histeridæ*, is large. The elytra do not cover the abdomen, but leave the last three segments exposed. The legs are long and slender.

The larva of *Scaphisoma agaricinum*, which may be taken as being fairly typical, resembles those of the *Staphylinidæ*, the cerci, however, being very short. The sides of the body bear long hairs. There is also a short anal process. Both larvæ and adults are found in mushrooms, where they feed on the tissues. Dr. A. Matthews has written on the family. Csiki lists the species in the Berlin Catalogue. There are four British species (Fowler).

Histeridæ.

Antennæ short, clubbed and elbowed. Tarsi five-jointed, tibia usually dilated. Elytra truncate, exposing two segments. Hind coxæ widely separated.

A large family of some 1,700 species, widely distributed throughout the world. They are easily recognizable by their compact form and hard integument. They are usually black and shining, with deep striations on the elytra. Some species have red or orange markings. The shape varies; the majority of species are very rotund, but there are others more elongate and very flat.

The mouth-parts are well developed, with strong mandibles. The head in some species is retractile. The antennæ are elbowed and clubbed, and concealed when not in use in a groove under the pronotum. The pronotum is large and closely

fits the elytra, which are truncate, leaving two segments exposed. The legs are short, stoutly built, with enlarged, toothed tibia.

The larvæ are elongate, more or less broad, with soft integument. They have well-developed mouth-parts with strong mandibles. The abdomen terminates in a pair of short, two-jointed cerci. The legs of some species, particularly the genus *Hister*, are very short. The adults of *Hister* and allied genera frequent dung, carcases, etc., and although it has been thought they feed on such matter, it is very possible they are predaceous on Dipterous and other larvæ which are to be found there. Some species are found living with termites, while others frequent ants' nests. The larvæ are carnivorous.

The family has been monographed in the *Genera Insectorum*, by Bickhardt, Fasc. 166 (1916). The species have been listed by Bickhardt in the Berlin Catalogue.

There are forty British species (Fowler).

Their habits either as scavengers or predators might be considered beneficial.

Niponiidæ.

Elongate, cylindrical. Antennæ elbowed, with three-jointed club. Tarsi five-jointed, the last nearly as long as the preceding four together. Clypeus with horn-like projections.

A small family containing only one genus of few species, found in Japan, India, and Borneo. They are small beetles, not exceeding 6 mm. in length; elongate and cylindrical in form and generally black or some other dull colour.

The head is broad and long, with the clypeus bearing short, horny projections. The mandibles are large and deflexed. The antennæ are elbowed and clubbed. The pronotum is long and broad, the elytra truncate, exposing two segments. The legs are stoutly built, the tibiæ being strongly toothed on their outer edge. They are diurnal in habit and are found frequenting timber affected with Scolytids, which they seek out in their borings.

Mr. G. Lewis has written of them (*Trans. Ent. Soc. Lond.* 1885).

Platypsyllidæ.

Small, wingless, eyeless. Antennæ three-jointed, tarsi five-jointed.

A family of only one species, which has been found in Europe and America. It is a small beetle of most abnormal characters, and it was for some time considered to belong to a separate order.

It has a large head in which the eyes are wanting and the mandibles very rudimentary. The antennæ are superficially three-jointed, but the knob-like third joint is made up of seven or eight very compact joints. The elytra are very short and wings are wanting. The legs are short, with five-jointed tarsi.

It has been found on the beaver; but whether it feeds there on other smaller parasites, or on skin exudations, does not seem to be clear. The larva is known to be elongate, narrowing in front and behind, and possessing a pair of short cerci and an anal process. This family has been monographed by Desneux in *Gen. Ins.* Fasc. 41 (1906).

(*b*) CLAVICORNIA

Antennæ usually clubbed.

Syntheliidæ.

Antennæ subgeniculate, clubbed. Tarsi five-jointed. Abdomen with eight or nine tergites and five sternites. Elytra not quite covering abdomen.

A small family of one genus containing six species, occurring in India, Eastern Asia, and Mexico. They are allied to the *Histeridæ* and are oblong and somewhat depressed in form. They have large heads, with strong mandibles; antennæ which are more or less elbowed and terminate in a broad, compressed club. The pronotum is long and broad, but does not fit the base of the elytra as in the *Histeridæ*. The legs are strongly built and have five-jointed tarsi.

Nothing seems to be known of the life-history. They have been found frequenting trees with running sap.

Sphæritidæ.

Antennæ short, eleven-jointed, clubbed, not geniculate. Tarsi five-jointed. Anterior and posterior coxæ contiguous, middle coxæ separated. Elytra truncate. Legs slender.

This family contains one species found in the West of North America, and Northern and Central Europe. It is a small insect bearing a superficial resemblance to some of the Histerids. The antennæ possess a three-jointed club, but are not elbowed. The pronotum fits closely to the elytra, which are truncate, leaving the apex of the abdomen exposed. The legs are slender.

It has been found in old fungi, in carcasses of small birds and mammals and in snails. The earlier stages are not known.

Trogositidæ (*Temnochilidæ*, *Ostomidæ*).

Antennæ clubbed on one side. Tarsi five-jointed, first joint small. Elytra covering abdomen. Hind coxæ contiguous, fore and middle coxæ more or less expanded.

A family of from 400 to 500 species, mainly found in tropical regions; but some of its members have been distributed about the world by commerce.

They are small insects varying much in form; some are round and convex, others elongate and cylindrical. Their colouring is usually dark. They have strong biting mouth-parts, short antennæ, with the apical joints laterally expanded; a well-developed prothorax; elytra which completely cover the abdomen, and fairly short legs.

A good distinguishing feature between them and the *Nitidulidæ* is the fact of their having the first and not the fourth tarsal joint very small. The larvæ are elongate and parallel-sided, with a large head and well-developed mandibles. The thoracic legs are short. The apical segment bears two short, chitinized processes. There are a few bristles on the sides of the body.

The adults of some genera (*Nemosoma*, *Temnochila*, and *Tenebrioides*) live in decaying trees on the larvæ of wood-

boring insects. Other species (*Ostoma*) inhabit fungoid growths on trees. The larvæ are questionably predaceous.

Rupertsburger has done some work on this family (1894). There are three British species (Fowler).

Tenebrioides mauritanica, a cosmopolitan insect, lives in stored grain, which it is accused of damaging. The larva certainly injures a lot of grain by eating out the embryo of each; but it is a question as to whether the adult does not feed more on the larvæ of other grain-infesting insects than on the grain itself. In any case, it is easily exterminated by means of heat and fumigants.

Helotidæ.

Antennæ short, with four-jointed club. Tarsi five-jointed, fifth longer than rest combined. Anterior coxal cavities round; coxæ widely separated. Two raised waxy spots on each elytron.

A small family of about forty species, occurring in Japan, Malay and certain parts of India. One species has been found in East Africa. In shape they are an elongate-oblong, with a metallic upper surface, much sculptured, and usually with four raised, yellowish, waxy spots on the elytra.

They have a small head, short, clubbed antennæ, and eyes set well back. In general characters they resemble the *Erotylidæ*. The first tarsal joint is very small, and the fifth is longer than the preceding four together.

They have been found feeding on the exuding sap of trees. The earlier stages still remain to be investigated. The species have been listed by Ritsema in the Berlin Catalogue.

Byturidæ.

Antennæ inserted before eyes, eleven-jointed, with three-jointed club. Tarsi five-jointed, fourth small; claws toothed. Coxæ narrowly separated, anterior coxal cavities closed behind. Five free ventral segments.

A family of only one genus comprising four species, two of which are found in Europe and two in North America.

They are small beetles, 3–4 mm. long, of a dull yellowish

tinge with grey or greenish pubescence. They resemble in general characters some species of the family *Nitidulidæ*.

The larvæ are cylindrical and have at the sides a few long hairs. The abdomen terminates in a pair of short cerci, and there is an anal process, said to assist locomotion. The pupæ are very hairy and are found in the soil, or sometimes in crevices of sticks. The adults frequent flowers, feeding on the petals, etc., especially those of the raspberry, loganberry and blackberry, of which latter the cultivated kinds are more often visited. On warm, sunny days the beetles may often be seen in flight. The two European species occur in Britain (Fowler).

The habits of the larval and adult stages of one of the British species (*Byturus tomentosus* F.) make it of economic importance inasmuch as greatly effects the quality and quantity of the raspberry crop of this country. Damage is done in the first place by the adult biting the blossoms and often destroying the reproductive organs. An egg is also laid by the beetle in the blossom as soon as it opens, the resulting larva eating its way to the receptacle, into which it burrows and from there eats portions of the surrounding fruit, which either becomes deformed or falls off. The grubs sometimes crawl from the damaged berry to a clean one, burrowing into it at its base. Pupation generally takes place in the soil or under the loose bark of the canes, the adults emerging in the following spring.

A good method of control is to dig well around the canes; also to burn all prunings.

Nitidulidæ.

Antennæ with a three-jointed club. Tarsi usually five-jointed, fourth joint small. Coxæ separate, outwardly prolonged. Elytra often truncate. Five free sternites.

A large family of some 1,500 species, widely distributed in both temperate and tropical countries.

They are an interesting family inasmuch as they vary greatly in shape, size, general structure and habits. They are mostly black or brown of colour, with or without markings, and are generally pubescent. They range from very small to moderate sized insects. Some are round and convex, some oval, and

others narrow and elongate. Some have abbreviated elytra and resemble Staphylinids, others have only the last two segments exposed, while others again have complete elytra.

The head is usually of moderate size. The antennæ bear a club, in some species round and compact, in others rather loose and oval. The thorax closely fits the elytra in the majority of cases. There are five visible ventral segments. The legs are short, stout, and in some species retractile. The tarsi are in nearly all cases five-jointed; but the posterior tarsi of the males of the tribe *Rhizophagina* are four-jointed.

The larvæ, several species of which have been described by Perris, etc., are elongate, with a smallish head and short antennæ. They more or less taper towards the apex, and have the last segment furnished with a pair of hooks. The legs are short. They are found in many situations: in flowers, on the parts of which they feed, in carcasses of animals, in rubbish or faggots and many other places. The adults likewise have the same diversity of habit, and occur in a variety of situations: at sap of trees, among bones, in rotting fruit, or on flowers, and the members of one genus (*Amphotis*) in ants' nests. Many act as scavengers, while others live on fresh food.

The family has been monographed in part by Murray (*Trans. Linn. Soc.* xxiv) and by Reitter (*Verh. Ver. Brunn.* xii). Fowler has written on the general characteristics of the family in the *Entom. Month. Mag.*, vols. xxi and xxii.

Grouvelle lists the species in the Berlin Catalogue.

There are ninety-two British species (Fowler).

The family cannot be said to be of economic importance, although members of the genus *Carpophilus* have been found among grain and dried fruits, and *Meligethes æneus* in the flowers of mustard, rape, and tobacco.

Cucujidæ.

Small, flat. Antennæ eleven-jointed. Tarsi four- or five-jointed. Pronotum often laterally toothed.

A family of some 450 species, distributed over the greater part of the world. The majority of them are quite small insects, but a few attain to more moderate size. In form they

are generally elongate, narrow, and depressed. They seldom show any other colouring than varying degrees of brown. The antennæ are inserted under the side margins of the front, and although they are usually long and slender at the apex, may in a number of cases be feebly clubbed. The mandibles are prominent and strong. The sides of the thorax are crenulate in a number of species. The elytra cover the abdomen. The legs are moderately long, usually with five-jointed tarsi; but in some males are four-jointed in the posterior legs, and in a few cases are all four-jointed. The larvæ vary much in shape. Some are very flat, others cylindrical and convex. Those of the genus *Brontes*, etc., have well-developed cerci and an anal appendage. In *Silvanus* the apical segment is quite simple; the pupæ, however, bear two short cerci.

The adults usually live under bark or in decaying wood; but quite a number of species are found in grain, rice, dried fruits, tobacco, etc. There are also a few which live in ants' nests.

The larvæ of the wood-infesting species are carnivorous, feeding on the larvæ of wood-boring beetles, particularly some of the *Scolytidæ*. There are eighteen British species (Fowler).

Silvanus surinamensis, which has become almost cosmopolitan, lives and breeds in sugar and dried foods, as well as in grain infested by other insects.

Monotomidæ.

Very small. Antennæ eleven-jointed, with solid club. Tarsi five-jointed, apparently three-jointed. Maxillæ free. Five free sternites, first and fifth longest. Pygidium exposed.

A family of about 100 species, which are widely distributed.

They are very small, somewhat elongate and depressed and usually of dull colouring.

The head is large, with short, strong mandibles. The thorax is crenulate at the sides. The elytra do not completely cover the abdomen, but leave the pygidium exposed. The females have five visible ventral segments and the males six. The adult beetles are found under bark and in rubbish. A few species inhabit the nests of ants. There are nine British species (Fowler).

Erotylidæ.

Antennæ eleven-jointed, with three- or four-jointed club, nserted in front of or between the eyes. Tarsi five-jointed, pparently four-jointed in some forms, the basal three broad nd pubescent. Elytra covering abdomen, five free sternites.

A large family, occurring in both temperate and tropical egions, but the majority of its members inhabiting the latter one.

They are subject to much variation in size and form and also f colour. Those found in temperate regions are usually small, nore or less oblong and without much distinctive colouring; ut the tropical species are larger, with more diversity of orm, some being nearly round and others elongate, and are ften much more highly coloured, especially in metallic blues nd greens.

The head is of moderate size, but varies somewhat in shape. The antennæ, which have a three or four-jointed club, are placed just in front of or between the eyes. The thorax in many cases has the sides slightly raised. The elytra completely cover the abdomen. There are five free ventral egments. The legs are of moderate length, with five-jointed arsi; the fourth is often very small and can easily be verlooked.

The larvæ of a few species are known: that of *Languria nozardi* is elongate, yellow of colour, with an anal appendage nd two curved, spiny cerci. The legs are fairly long. The arvæ of the sub-family *Erotylinæ* are somewhat broader and ot always furnished with cerci and an anal appendage. The egs are very short.

The adults and larvæ of the sub-family *Languriinæ* frequent ow bushes and plants: the larvæ in many cases living in the tems. The *Erotylinæ* are more confined to forest regions, here they live in fungus growths on timber. The former of hese sub-families has been listed by Fowler (*Gen. Ins.* Fasc. 8, 1908) and the latter by Kuhnt (*Gen. Ins.* Fasc. 88, 1909). Horham has worked on some of the Indian species (*Ann. oc. Ent. Belge.* 1895 and 1903). The species are listed in the Berlin Catalogue.

There are only six British species.

In America, one species, *Languria mozardi*, Lac., injures the clover crop to some extent, by the larvæ boring in the stems.

Cryptophagidæ.

Small. Antennæ eleven-jointed, usually with a three-jointed club. Tarsi five-jointed, sometimes heteromerous in the males. Elytra covering abdomen, upper surface more or less pubescent. Five visible sternites, first longest.

A family of some 500 odd species, found in both temperate and tropical regions.

They are small beetles, not exceeding 4–5 mm. in length; obscure of colour and generally pubescent above.

They possess inconspicuous biting mouth-parts. The sides of the pronotum are slightly toothed. The elytra are often pubescent, in some cases having a thick covering of hairs. The first ventral abdominal segment is in all cases the longest. As stated above, the tarsi are usually all five-jointed; but in the males of some species the posterior tarsi are only four-jointed.

The larvæ are elongate, but do not possess cerci or anal appendage.

Both larvæ and adults occur in a variety of situations: in fungi, mould, or decaying vegetable matter; on flowers or under bark. The larvæ of the genus *Antherophagus* have been found in the nests of bumble-bees; while some species of *Cryptophagus* occur in wasps' nests and others of *Atomaria* in ants' nests. It is presumed that the larvæ found in association with other insects act as scavengers.

There are sixty-nine British species (Fowler). *Atomaria linearis*, has been known to attack beet in Europe.

Catoprochotidæ.

Minute. Antennæ very short, eleven-jointed, compact, but not clubbed. Tarsi five-jointed. Middle and hind coxæ widely separated. Pronotum as broad as base of elytra, which do not quite cover abdomen.

A family of few species, found in Turkestan.

They are very small beetles, not exceeding 3 mm. in length.

They resemble somewhat the *Corylophidæ*, but are not so ound in form.

The antennæ are very short and inserted under the side nargins of the forehead. The anterior coxæ are separated y a prosternal process. The elytra do not quite cover the bdomen.

Little seems to be known as to the habits and life-history f these insects.

Phalacridæ.

Very small, compact, convex, smooth and shining. ntennæ eleven-jointed, clubbed. Tarsi five-jointed, fourth oint often very small. Front coxæ globular, hind coxæ ontiguous. Elytra cover abdomen. Head sunk into ronotum.

A family of about 300 species occurring in all parts of the orld.

They are very small, compact insects, oval in form, and enerally smooth and shining; black or brown of colour.

The head is sunk into the pronotum and half concealed. he antennæ are more or less clubbed. The legs are short nd stout.

The larva of one species, *Olibrus affinis*, has been described y Laboulbene, as having a narrow head, a broader pronotum, ith two dorsal plates, and a somewhat broad anal process. he larva of *O. bicolor* has short cerci, but no anal process.

The adults are usually found on herbage, often on the ower-heads of the *Compositæ*. Occasionally they occur in oss. The larvæ of the flower-frequenting species are said o bore down the stems and pupate in earthen cocoons.

There are fifteen British species (Fowler). None are of conomic importance.

Thorictidæ.

Very small. Eyes small or rudimentary. Antennæ short, leven-jointed, clubbed. Tarsi five-jointed. Scutellum not isible, elytra connate at suture, covering abdomen.

A small family of two genera, found only in the Mediterranean gion.

They are very small insects, rarely exceeding 2 mm.

The antennæ, which are short and thick, have a club which appears to be solid, but is really three-jointed. The eyes are small, and in some species very rudimentary. The scutellum is not visible, and the elytra, which cover the abdomen, are soldered together at the suture. The legs are short and stout. These beetles possess little tufts of yellowish-golden hair, in some species situated on the ventral surface of the body, in others at the hind angles of the prosternum.

The adults are found in the nests of ants, particularly *Myrmecocystus*. They have often been noticed clinging to the scape of the antennæ of the ants, and it has been suggested by Wasmann that this habit enables the ants to reach the above-mentioned tufts of hair, which secrete some substance appreciated by the ants.

Derodontidæ.

Small, coarsely punctured. Antennæ almost filiform, slightly thickened towards the apex. Legs slender, tarsi five-jointed, simple. Elytra cover abdomen. Five free ventral segments.

A small family of nine species, occurring in Europe, North America, and Japan.

They are small and coarsely punctured; oblong or oval in form. Their eyes are prominent and their antennæ almost filiform. The members of the genus *Derodontus* have a round thorax, toothed at the sides. The elytra completely cover the abdomen. The legs are slender, with five-jointed tarsi.

The life-history is unknown.

They have been listed by Schenkling in the Berlin Catalogue.

There are no British representatives.

Lathridiidæ.

Tarsi three-jointed. Pronotum narrow. Abdomen with five or six free ventral segments.

A family of some 700 species, occurring in all parts of the world.

They are small beetles, not exceeding 3 mm. in length;

elongate-oval in shape; pubescent in some species and bare and shining in others. The head is proportionally big. The mandibles not very well developed. The antennæ, which have the last two or three joints expanded to form a loose club, are inserted in front of the eyes. The thorax is often much narrower at the base than the elytra, which are in many cases strongly punctured and ribbed. The legs are long and slender, with three-jointed tarsi.

The larvæ are elongate, oval, soft, whitish in colour, with markings in some species, and clothed with hairs of varying length. The thoracic segments are larger than the others. The last abdominal segment possesses a short process, acting as a proleg. The mandibles are fleshy. The pupæ are whitish, and bear short hairs on and near the face. Both stages are found in moss, decaying wood, powdery fungi, and various kinds of vegetable refuse. There are also a few myrmecophilous species. They feed on dead animal or cryptogamic matter.

The family has been monographed by M. J. Belon in the *Genera Insectorum*, Fasc. 3 (1902). There are thirty British species (Fowler).

Mycetophagidæ.

Antennæ eleven-jointed, thickened towards the apex to form a club. Tarsi four-jointed, except the anterior pair in the males, which are three-jointed. Five free, equal, ventral segments.

A family of some 100 species, distributed over the greater portion of the world. The members of this family are small, usually elongate-oblong in shape; more or less pubescent, and in many cases brightly coloured, especially with orange or yellow markings. The head is small. The clubbed antennæ are inserted in front of the eyes, under the side margins of the forehead. The legs are slender, and of moderate length. The males are recognizable by the fact of their anterior tarsi being only three-jointed. The thorax and elytra are usually more or less punctured and pubescent.

The larvæ of a number of species have been described by

Perris as being elongate and parallel-sided, with a few long, lateral hairs, the abdomen terminating in a pair of short, hooked cerci and also a very small anal tube. The legs are short. The adults are found under bark, in fungi, amongst the rubbish at the bottom of haystacks, and occasionally in granaries. They are presumably fungus-feeders in both larval and adult stage.

There are eleven British species (Fowler).

Colydiidæ.

Mostly elongate and cylindrical. Antennæ short and clubbed, eight- to eleven-jointed. Tarsi four-jointed, simple. Elytra covering abdomen. Five visible sternites, anterior ones connate.

A family of some 600 species, with representatives in most parts of the world.

These are small to moderate-sized beetles of varied form. The majority of them are elongate and cylindrical. They are usually black or dull brown of colour.

The antennæ are usually ten- or eleven-jointed, but there are a few species in which they are only eight-jointed. The club in some cases is solid. The thorax and elytra are often very markedly sculptured, in the same manner as many of the *Lathridiidæ*. The eyes are of moderate size, but one species, *Langelandia anophthalma*, which lives always underground, is blind.

The larvæ of some species are known: that of *Ditoma crenata* is elongate and linear, with all its segments of about equal size, the last one terminating in a pair of short, horny processes. The head is somewhat narrow and the legs short.

The adults live in fungi, old stumps and under bark of trees. The members of one genera, *Langelandia*, live underground. Others again, belonging to the genus *Colydium*, have been found in the burrows of wood-boring beetles, where they destroy the larvæ.

The family has been classified by Sharp (*Biol. Centr. Amer.* 1894).

There are sixteen British species (Fowler).

Adimeridæ.

Minute. Tarsi apparently two-jointed, really four-jointed, first joint very broadly dilated, last joint elongate.

A small family of one genus, containing three species, only found in Central America and Brazil.

In general appearance they resemble the *Colydiidæ*.

The formation of their tarsi is of interest inasmuch as although they appear to be two-jointed, they are really four-jointed; the basal joint is much dilated and practically conceals two minute joints at its base. The last joint is elongate.

Nothing is known of the life-history.

Endomychidæ.

Antennæ long and clubbed, inserted between the eyes. Tarsi four-jointed, apparently three-jointed, basal two broad. Five free sternites, the first longest.

An extensive family of some 600 species, distributed over the greater part of the world, the majority, however, being found in tropical regions.

The members of this family show much diversity both of form and colour, many being possessed of unusual shape and striking colouring, particularly red and black. Some species are very small, only 1 mm. in length, while others, particularly those found in the tropics, attain a length of nearly an inch.

Fig. 47. — *Endomychus coccineus.* (× 4.)

The head is small and the mouth-parts not very conspicuous. The antennæ have a somewhat flat three-jointed club. The legs are rather longer than those of the Coccinellids. The elytra in some species are produced, with a slight upward slope, beyond the sides of the body. In some other species the elytra bear a number of strong upright spines.

The larvæ of a few species are known: that of *Endomychus*

coccineus L., a British species, much resembles certain Silphid larvæ. Others are described by Bates as being oblong-oval, somewhat convex and more or less hairy, and possessing moderately long antennæ. Both larvæ and adults are found under bark or in cracks or crevices of trees, where they feed on fungoid growths.

The family has been worked upon by Gorham (*Biol. Centr. Amer.* VII).

Fowler describes five British species.

Coccinellidæ.

Ladybird beetles.

Round, convex. Antennæ eleven-jointed, with slight club. Head deeply sunk into prothorax. Legs short, usually strongly retractile. Tarsi four-jointed, basal two pubescent, third minute and concealed. Claws toothed.

A family of over 2,000 species, widely distributed throughout the world.

The members of this family are the well-known "ladybird beetles," their characteristic round and convex form greatly aiding distinction from most other families. There are, however, several species of a more oblong-oval shape. They are usually shiny, red, or yellow, with a greater or less number of black or brown spots. They are typical instances of warning coloration, being possessed of a very unpleasant acrid flavour, extremely distasteful to birds. Several species are somewhat pubescent and less brightly apparelled.

The family may be clearly divided into two groups; one group, the *Epilachninæ*, containing herbivorous species, and the other, the *Coccinellinæ*, carnivorous species. By far the greater number belong to the latter group.

The general characteristics are: a smallish head, deeply sunk into the prothorax and bearing, in the *Coccinellinæ*, simple, or bifid mandibles, and in the *Epilachninæ* mandibles of the herbivorous type. The antennæ are shorter than those of the preceding family, the *Endomychidæ*, and are only feebly clubbed. The thorax is as broad at base as the elytra, which entirely cover the abdomen. The legs are short and more or

less retractile, with four-jointed tarsi, the third joint of which, in the majority of cases, is extremely small and concealed. The sexes do not differ much in external characters, although the males are in some cases smaller ; also there is often a slight modification in the structure of the apical ventral segment of the males.

The eggs are laid on end in clusters openly on plants, and are cigar-shaped and generally yellow. The larvæ are elongate, broadest across the base of the thorax and tapering sharply to the apex of the abdomen. The mouth-parts are well developed. The legs are moderately long. The coloration varies, but is usually conspicuous, often being greyish with a varied number of yellow or reddish markings. The body is often covered with spines and tubercles. Pupation takes place on the plant, the larvæ attaching themselves to the leaf by the apical segment with the aid of a sticky secretion. The anterior part of the body is drawn up toward the apical end ; the split larval skin shrinks into a wrinkled mass, but is not entirely cast off the pupa. Some larvæ are able to cover themselves with a waxy secretion from pits in the body, causing them to resemble mealybugs.

The life-history in the majority of cases is short, all stages being gone through in three weeks. There are several broods per year. Hibernation takes place as adults, large numbers being found in the winter, congregated under loose bark or in cracks. They are often found behind pictures in rooms and in the window frames.

Both larval and adult stages of the carnivorous species feed voraciously on aphids, scale insects, mealybugs and white fly, and are therefore very beneficial. *Thea cincta* feeds on the fruiting bodies (*Perithecia*) of a mildew (*Phyllactinea corylea*) which grows on the foliage of mulberry. The *Epilachninæ* are herbivorous and feed on the epidermis of the leaves, especially of Cucurbitaceous and Solanaceous plants. Their larvæ are less active and are more oval in shape. They pupate in the same manner as the *Coccinellinæ*.

Gorham is an authority on this family. Weise and Stettiner also have done some work on it. Fowler describes the forty-two British species. Only one of them belongs to the herbivorous group.

The family as a whole is of great economic importance by virtue of its carnivorous species: immense numbers of aphids, etc., being eaten by these beetles. To take only one example, that of *Chilomenes sexmaculata*, which lays about ninety eggs on the leaves of the cotton plant; it has been estimated that one of the larvæ resulting from these eggs eats about 2,400 cotton-infesting aphids in the course of its existence. The *Epilachninæ*, when abundant, may do a certain amount of damage, particularly to *Solanaceæ* and *Cucurbitaceæ*.

Dermestidæ.

Antennæ clubbed, concealed in a groove under pronotum. Head usually with frontal ocellus. Legs short, retractile; tibiæ sometimes with distinct spurs. Tarsi five-jointed, claws simple. Surface often pubescent or scaly.

This family, which is of moderate size, has a wide distribution, the greater number of its members, however, inhabiting temperate regions. Their habits have caused a number of species to become almost cosmopolitan in range, they being carried about the world by commerce.

In shape these beetles are oval or oblong, and are of small size, seldom exceeding 10 mm. in length. They are generally of a dull black or grey colour and have a covering of fine hairs or scales, which in some species form a pattern on the elytra. The antennæ, which are short and clubbed, are capable of being concealed in a groove under the pronotum. In some species there is an ocellus situated on the frontal portion of the head. The head is more or less retractile. The apical joint of the antennæ of the males of some species is enlarged.

The larvæ, generally, are notorious as being serious damagers of dried goods such as skins, horns, wool, etc., also cheese and bacon. The larvæ of the genus *Anthrenus*, of which the adult beetles frequent flowers, are particularly harmful as ravagers of collections of Natural History specimens. The appearance of the larvæ is peculiar and interesting, owing to their furry upper surface, which makes them resemble some of the Lepidopterous larvæ. The head is small, with short antennæ and usually six ocelli on each side. The legs are short, and the body is covered with a somewhat thin skin, clothed in places

with tufts of long hair. The larvæ of *Tiresias serra*, which lives under loose bark among cobwebs, etc., has been described and figured by Sharp, who says that the three posterior segments of its body bear on each side tufts of long brown hair, which are capable of being raised or lowered at will. Pupation takes place in the larval skin, which splits along the dorsal surface, but is not cast off the pupa. It is curious to note that the life-history can be prolonged in every stage if food is scarce or conditions unfavourable. Both larvæ and adults can live for some time without nourishment; while the eggs will remain as they are if they should chance to be in a position not advantageous to the larvæ on emergence. The adults are, as a rule, comparatively harmless.

The family has been listed by Dalla Torre in the Berlin Catalogue.

Fowler describes the twelve British species.

The species of most economic importance are: *Dermestes lardarius*, which is cosmopolitan in range and attacks bacon. *D. vulpinus*, also cosmopolitan, which destroys hides, etc., and in India ravages the cocoons of silk moths. *Anthrenus vorax*, in India, attacks wool, hides, etc. *A. scrophulariæ*, in America, attacks carpets and woollen goods. *Trogoderma khapra*, in India, attacks grain, and is now established as a pest of barley in England: the last is particularly dangerous, as it attacks dry grain and will probably become cosmopolitan. Its introduction to Australia, the Argentine and the United States will be a serious matter, but, in the absence of any precautions, will certainly take place.

Byrrhidæ.

Pill beetles.

Oval, very strongly convex. Head with vertical forehead. Antennæ clubbed and inserted between the eyes. Tarsi usually five-jointed. A prosternal spine fitting into a mesosternal cavity.

A family containing about 300 species found in both temperate and tropical regions.

The popular name of "pill beetles" is an apt description of

the appearance of the Byrrhids, when on alarm they press their legs to their bodies and remain motionless : while their colour often resembles the ground to which they fall when disturbed.

The antennæ are thickened towards the apex, forming a club, and are inserted between the eyes. The head in all species is retractile ; the mouth-parts being almost concealed by the prosternum. The legs are short, stout, and strongly retractile, the femora being provided with a furrow for the reception of the tibiæ when the legs are retracted. The elytra cover the abdomen. The integument, generally, is somewhat hard.

Of the complete life-history little is known. The larvæ of a few species have been described. That of *Byrrhus pilula*, a well-known British species considered to be typical of the family, is a cylindrical, soft creature, with a broad head, and the prothoracic and the last two abdominal segments larger than the others. The last segment bears a pair of short pseudopods. The larva spends part of its time under the turf ; but may sometimes be found on the surface. The adults of the genus *Byrrhus* frequent roots of grass, low plants or moss on which they feed. Others may be found on the leaves of plants.

Sharp has done some work on this family. A list of the species by Dalla Torre will be found in the Berlin Catalogue. Fowler deals with the twelve British species. No members of this family need be considered in an economic aspect.

Nosodendridæ.

Oval, very convex. Head prominent, mentum large. Antennæ clubbed, inserted in front of the eyes. Tarsi five-jointed ; legs short, retractile.

A family consisting of one genus, containing about twenty-eight species. They are, however, fairly widely distributed, being found in Central and North America, Ceylon, and most of the European countries.

In general appearance they resemble the *Byrrhidæ*, under which family they have been included by some authors.

They differ from the Byrrhids in having the head prominent

and the mouth-parts somewhat concealed by a large mentum. The clubbed antennæ are placed in front of the eyes under the side margins of the forehead. The abdomen is completely covered by the elytra. The legs are short and retractile and possess the grooved femur in common with the Byrrhids.

It is in the larvæ that the chief difference between the two families lies ; those of the Nosodendrids being broad and more like woodlice in general appearance. They also possess curious stalked spiracles on tubercles, and short, recurved, lateral processes on the first seven abdominal segments. The longest and pear-shaped eighth segment does not carry cerci. The larva of *Nosodendron fasciculare* has been described by Ganglbauer.

The adults have usually been found near wounded trees with flowing sap, upon which they presumably feed. *N. mexicanum* inhabits more muddy places.

Dalla Torre has listed the species in the Berlin Catalogue. There are no British species.

Cyathoceridæ.

Minute insects of broad form ; parts of the mouth concealed. Antennæ four-jointed. Tarsi not divided into joints ; prosternum small (Sharp).

This aberrant family contains only one species, which has been described by Sharp as having the above features. It is found in Central America. The life-history is unknown.

Georyssidæ.

Small, compact. Antennæ nine-jointed, last three forming a club. Legs long, tibiæ slender, tarsi four-jointed.

A family of one genus containing about twenty-four species well distributed throughout North America, Ceylon, Europe, and Australia.

They are all small beetles of compact build, with a large, downwardly deflected head. The antennæ are inserted under the sides of the front portion of the head and bear an oval club. The thorax is closely fitted to the elytra, which completely cover the abdomen. The legs are long and slender.

The anterior coxæ are somewhat prominent and, by their being flattened into plate-like structures at the tip, conceal the prosternum. The colouring is black or dark brown and the elytra are coarsely sculptured.

Their habitat is sandy or muddy places at the foot of cliffs, or sometimes under stones in running water. They have the curious habit of coating themselves with mud or sand, a proceeding which causes them to blend well with their surroundings. This coating is said by Erichson to be retained on the back by the aid of a gummy secretion. The characteristics of the earlier stages still remain to be discovered.

A list of the species by Zaitzer will be found in the Berlin Catalogue.

There is only one British species.

Dryopidæ (*Parnidæ*, including *Elmidæ*).

Variable form. Head usually, retractile. Antennæ very variable. Tarsi elongate, five-jointed, last joint large. Eyes round, sometimes hairy. Prosternum produced in front and behind.

A family containing about 550 species of fairly wide distribution, the greater number being found in Brazil, Mexico, and North America. Europe and India also have representatives.

These beetles vary greatly as to shape, but are all small insects, usually black or bronze in colour. Some are oval, or oblong-oval, others are more elongate and somewhat cylindrical. They are often clothed with a fine pubescence. The family is usually split up into two groups : the *Elminæ* and the *Dryopinæ* or *Parninæ*.

The head is small and usually retractile. The antennæ differ in the two groups, those of the *Elminæ* being long, filiform or serrate, while in the *Dryopinæ* they are very short, and have in some cases the second joint dilated. The eyes are sometimes hairy. The elytra completely cover the abdomen. The legs are slender, and in some species very long. The larvæ of the two groups differ much in form. Those of *Dryopinæ* live under stones in damp places and are narrow and elongate, with some resemblance to the larvæ of the

Elateridæ. *Elminæ* have elongate larvæ, oval and narrowing behind, with the segments laterally furnished with long hairs. The last segment terminates in a longish, thin process, bearing three sets of filaments, which are said to be used in respiration. They inhabit running water, attaching themselves to stones, etc., as do also the adults, the pubescent under-surface of their bodies enabling them to carry down a supply of air. The adults of the *Dryopinæ* occur in damp places under stones, etc.

Kletkl has done some work on the family, and a list of the species will be found in the Berlin Catalogue.

The fifteen British species are dealt with by Fowler.

Hydrophilidæ.

Size variable, ½ mm. to 50 mm. long. Antennæ six- to nine-jointed, inserted in front of eyes, basal joint long, remainder forming club, apical joints broadened, fitting below head. Tarsi five-jointed, basal joint often small. Maxillary palpi often longer than antennæ.

This is a large family containing well over 1,000 species. They are widely distributed, tropical regions having a greater number of species than temperate countries.

In size they vary greatly, for while there are a considerable number of small and minute species, there are also many of medium size, and some which attain a length of close on two inches. They are compactly built and usually oval in shape, especially in the aquatic forms. Some of the terrestrial and sub-aquatic species are oblong, while many are spherical. Bright colours are not seen in this family, most of its members being brown, yellowish, or black.

The antennæ are short, with the apical joints forming a broad club, which is often pubescent. The maxillary palpi are of unusual length, sometimes being longer than the antennæ. The eyes are larger and in some cases almost divided. The legs are long, and in the aquatic species are furnished with swimming hairs. The first tarsal joint is in some cases very small.

The majority of these beetles are aquatic, living in ponds, ditches and streams of both fresh and brackish water. Others are sub-aquatic and terrestrial, living in mud, dung, refuse, etc.; some are found under the bark of trees.

The earlier stages of some of the aquatic species are known. Miall, in his *Aquatic Insects*, gives an excellent account of the life-histories of *Hydrophilus piceus* and *Hydrobius fuscipes*. The eggs are neatly packed in a case fitted with a mast-like structure and attached to an aquatic plant at the surface of the water or floating free. The larvæ, which resemble somewhat those of the Dytiscids, are elongate, tapering sharply toward the apex. The mandibles are smaller than those of the Dytiscids, and the larvæ, although carnivorous, are less rapacious. Pupation takes place in damp earth near water. The larvæ have spiracles at the apex of the body, through which the air supply is obtained. The larvæ of other aquatic species vary much in form. The adults are principally herbivorous.

The sub-aquatic and terrestrial species, which belong to the sub-family *Sphæridiinæ*, are herbivorous in both larval and adult stages, acting in many cases as scavengers of decomposing vegetable matter. Their larvæ are very unlike those of their aquatic relations, being grub-like and practically destitute of legs. They are found in the roots of grass, in refuse, in moss, in the dung of herbivorous animals, under stones in damp places, etc.

Schiödte has figured and described the larvæ of many species (1861–1873). Fowler has described the larvæ and habits of several of the British species. Regimbart also has described many species. The British species number ninety-seven.

Helophorus rugosus may do a certain amount of damage to the roots of cruciferous crops, such as turnips; but it has also been found feeding on the larvæ of *Ceutorrhynchus*, a species of weevil, which forms galls in turnips.

Heteroceridæ.

Small, densely pubescent. Antennæ with seven-jointed club. Head large, sunk into prothorax as far as eyes. Labrum and mandibles projecting forward. Tarsi four-jointed; legs armed with spurs.

A family of one genus, comprising some 100 species which have a wide distribution, the majority, however, inhabiting temperate regions. India, Cuba, and Australia have a few representatives.

They average in size about 5 mm., and are oblong-oval in shape. They are clothed with a greyish pubescence, amongst which longer hairs are dispersed. The elytra are often marked with red or yellowish bands or spots.

The head is large, the fore part rather prominent, while the basal part is sunk into the thorax as far as the eyes, which are half concealed. The antennæ are short and from the third joint gradually thicken into an oblong club. The thorax is well defined and does not fit very closely to the elytra which completely cover the abdomen. The legs are moderately long and stoutly built, the tibiæ being broad, toothed and well adapted for burrowing. The tarsi, which by some authors are said to be five-jointed, are capable of being doubled back against the tibiæ when digging operations are in progress. The abdomen possesses at its base on each side a raised, curved line against which the posterior femora are said to rub, producing a sound, on occasion of alarm.

The larvæ are of curious form, having a large head with well-developed mandibles and small eyes; a thorax which greatly exceeds the head in width, and an abdomen much narrower than the thorax, with a slight taper towards the apex, which bears a small pseudopod. The legs are short. The entire surface is thickly pubescent.

Both larvæ and adults live by ponds, ditches, or streams, where they excavate galleries in the soft mud. Their movements are somewhat sluggish; but they will sometimes fly if disturbed. They are presumed to be predaceous; but it is also thought that they live on the mud of their burrows.

A list of the species will be found in the Berlin Catalogue. There are eight British species dealt with by Fowler.

(*c*) SERRICORNIA

Dascillidæ (*Psephenidæ, Cyphonidæ*).

Antennæ usually serrate, eleven-jointed, in front of eyes. Tarsi five-jointed. Anterior coxæ with large, distinct trochantin.

A small family of wide distribution.

These beetles are from small to moderate size, oblong-oval

in shape, dull of colouring, and often clothed with a thick pubescence.

The antennæ are as a rule serrate and inserted just in front of the eyes. The mouth-parts are rather peculiar, inasmuch as the outer lobe of the maxillæ is divided into two long laciniæ which project beyond the inner lobe. The labium also is divided. The legs are of moderate length, and the anterior coxæ have quite a distinct trochantin. The tarsi are in some cases provided beneath with membranous lobes.

The larva of *Dascillus*, as described by Gahan, is short, broad, and somewhat stout, narrowing slightly towards the apex. It has a large head with strong mandibles well adapted for crushing. The four-jointed antennæ are short. The legs are fairly long. It is believed to live under the ground in the roots of plants. The adult insect is usually found on flowers, Umbelliferæ in particular.

The family has been listed by Pic in the Berlin Catalogue. There is only one British species.

Helodidæ.

Small, delicate, soft integument. Antennæ filiform, slender. No trochantin on anterior coxæ. Larvæ have long antennæ.

A family of some 500 known species, found in most parts of the world.

These beetles are small, oblong-oval in shape and usually of a pale or brownish testaceous. They are often pubescent. The head is of moderate size; the eyes prominent and the antennæ filiform, except in the males of a few species, in which they are serrate. The mandibles are in some cases curved and pointed, in others short and blunt. The elytra cover the abdomen and, as is the case with the whole integument, are of flimsy structure. The anterior coxæ, unlike those of the *Dascillidæ*, to which this family is allied, do not possess a trochantin. The posterior legs of some species are formed for leaping.

The larvæ, which are short, broad, and somewhat onisciform in appearance, have antennæ which are in nearly all cases long

and many jointed. The legs are short. The sides of the body are fringed with short cilia. The larvæ of the genus *Helodes*, which live on aquatic plants, only possess abdominal spiracles and breathe by taking down a bubble of air at the posterior end of the body. The larvæ of all species are more or less aquatic, some living on bushes over streams and entering the water on occasion, others being found in the water accumulated in the hollows of trees. Some species are considered to be carnivorous. The adults are chiefly found on herbage in marshy places.

Tournier has described some of the larval habits, and a list of the species will be found in the Berlin Catalogue. Fowler mentions the fourteen British species. The family is not of economic interest.

Rhipiceridæ.

Large. Antennæ flabellate, or pectinate in males. Tarsi five-jointed, setaceous onychium. Anterior coxæ contiguous, with a trochantin; intermediate pairs separate.

A family of some 200 species widely distributed throughout tropical countries.

They are all large fine-looking insects, elongate in shape and easily recognizable by their conspicuous antennæ. The head is large and the eyes fairly prominent. The antennæ of the males bear very long processes and in some species have a great many joints; the females have serrate antennæ. The abdomen is entirely covered by the elytra. The anterior coxæ bear a large trochantin. The five-jointed tarsi have a broad, hairy onychium extending between the claws.

Little is known as to the life-history. Schiödte has described the larva of one species, *Callirhipis dejeani*, as being much larger than the adult insect, cylindrical, with a curiously truncate apical segment. It is said to live in wood. The adult insects are found on plants, trees, etc.; the species of the genus *Sandalus* are said to frequent cedars.

Leconte and Horn have made observations of several species, and the family has been listed by Csiki in the Berlin Catalogue. There are no British species.

Cantharidæ (*Telephoridæ, Malacodermidæ*).

Usually elongate. Body loosely jointed. Antennæ usually filiform or serrate, eleven-jointed. Tarsi five-jointed. Seven or eight visible sternites. Trochantins of fore coxæ distinct. Some females wingless.

This family is made up of four groups: the *Lycinæ*, *Lampyrinæ*, *Cantharinæ* and *Drilinæ*, which are considered by some authors to be separate families; but it seems more reasonable to place them under one heading. Sharp classes them together under the name *Malacodermidæ*. The total number of species as at present known amounts to over 3,000. They have a wide distribution in both temperate and tropical regions. The majority of the *Lycinæ* belong to the tropics, as do perhaps the greater portion of the *Lampyrinæ* and *Drilinæ*; the *Cantharinæ* chiefly inhabit temperate countries.

They vary in length up to about three-quarters of an inch, and are all more or less elongate, with soft integument, and as a rule quietly coloured, although quite a number of species are bright red or yellow. A flattened form of body is characteristic of them. The head is usually somewhat concealed by the pronotum, and carries eleven-jointed antennæ, generally filiform or serrate, but in some cases flabellate or plumose. The mandibles are of the predaceous type, but not very strong. There is a large, rather flat pronotum, which nearly conceals the head and loosely fits the elytra, which are weak and not closely adapted to the abdomen. There are seven or eight visible ventral segments. The legs are moderately long and slender, with five-jointed tarsi. The females of a number of species have neither wings nor elytra, and remain larviform, in such cases often being luminous. Many of the males have much larger eyes than the females.

The *Lycinæ* in many cases have dilated and leaf-like elytra. They are found most commonly on the flowers and leaves of plants. The larvæ are flat, narrowing in front and behind, with short thoracic legs and a chitinous apical segment terminating in two horny, curved processes. Both larvæ and adults are carnivorous.

The *Lampyrinæ* are nocturnal and generally found in grass

and low herbage. The well-known "glow worms" are contained in this group. The males, which attain to ordinary beetle-shape, are not remarkable, except that many of them possess to a greater or less degree the power of giving light. The females, however, remain larviform, so much so that it is often difficult to distinguish the larvæ from adult females. The "glow" shed by the females emanates from the underside of the apex of the abdomen, and is sometimes very bright. Its function is presumably to serve as an attraction to the males. The *Lampyrinæ* are carnivorous, many of them feeding on snails.

The *Cantharinæ* are all narrow, elongate insects, with delicate integument. Both the sexes attain true beetle form. The genus *Cantharis* contains the well-known "soldier beetles" which may be seen during the greater part of the summer, resting on plants and flower-heads, particularly the Umbelliferæ. The larvæ are elongate and velvety, with a flattish head and short antennæ. There is a sort of proleg on the anal segment, but no cerci. Both larvæ and adults are carnivorous. The larvæ live in grass or under loose bark. (*Cantharinæ* are usually known as *Telephorinæ*.)

The *Drilinæ* are somewhat small insects. The female of *Drilus flavescens* is a long, larviform, hairy creature with twelve segments, the last terminated by a round appendage and two short processes. The male is much smaller than the female, and has long, pectinate antennæ. The larva is very much like the female; it eats snails, pupating in the empty shells.

The *Lampyrinæ* and *Drilinæ* have been listed as separate families by Olivier in the Berlin Catalogue, and the former was monographed by the same author in *Gen. Ins.* Fasc. 53 (1907). A paper has been written on the *Drilinæ* by Bayford, 1906. There are also papers by Gorham, Bourgois, and Waterhouse.

The British species number fifty-nine, and are listed by Fowler.

No members of this family have been recorded as pests.

Melyridæ.

Like Cantharidæ, but abdomen with only six sternites. Claws often furnished with a membranous appendage beneath.

This family contains a large number of species of wide distribution, although chiefly in temperate regions.

They are variable in shape, some being rather short and broad, while others are much longer and narrow. Usually their colouring is bright, blue or green with red or orange markings being characteristic.

The head is of moderate size and is well produced in front of the eyes. The antennæ, which are either filiform or serrate, are inserted on the sides of the frontal part, except in the genus *Malachius*, in which they are more between the eyes. There is quite a distinct labrum. The members of the sub-family *Malachiinæ* possess curious, fleshy vesicles at the sides of the thorax and abdomen: these vesicles are capable of being extended and contracted and it is probable they emit an offensive odour. The elytra of some species cover the abdomen while in others the apex is left slightly exposed. The abdomen has only six visible ventral segments, which character forms a distinguishing feature between this and the preceding family. The legs are long and slender and are provided beneath the claws with a membranous lobe or pad-like appendage. The integument is as a rule weak, but tends to hardness in some forms. The larvæ of several species have been described by Perris. They are all much alike, elongate and sublinear, slightly narrowed in front and behind, with a rather long, narrow, hairy head and single long setæ at the sides of the abdominal segments. The legs are comparatively long. The head and the last segment, which terminates in two chitinous and somewhat hooked processes, are dark, while the ground colour of the rest of the body is pale or livid rose with spots or patches on the front parts.

The adults frequent flowers with the exception of a few species which live in rotting wood. There seems to be some doubt as to their food habits; but it is probable they are carnivorous, although they are said in some cases to consume parts of flowers. Fowler lists eighteen British species.

Cleridæ.

Antennæ clubbed, dentate or flabellate. Tarsi five-jointed, joints two to four furnished with lamellæ. Head and thorax narrower than elytra. Body cylindrical, sides parallel.

A large family of over 2,000 species, the majority of which are found in tropical countries, although there are a considerable number of representatives in temperate regions.

These beetles show much variation in shape, colour and size, some being short and moderately broad, while others are long and narrow. They are all somewhat small. As regards colour, although a few species are somewhat dull and obscure in appearance, by far the greater number are brightly coloured, many showing a warning type of coloration, while others very successfully mimic other insects.

The head and eyes are prominent; the antennæ of some species are simple; but in others may be clubbed, serrate or flabellate: they are inserted laterally on the front portion of the head. The prothorax is distinct. The elytra are much broader than the head and thorax and completely cover the abdomen. Wings are functional and often used. The legs are moderately long and built for running. They are furnished beneath the 2–4 tarsal joints with membranous appendages.

The larvæ of these beetles are elongate and as a rule reddish-brown or pinkish with various markings. They are usually fairly pubescent and have corneous plates on the thorax and last abdominal segment, which last often bears two short, projecting processes and a short anal appendage.

The adults are found in various situations: on flowers, grass, tree-trunks, etc., in carcasses and amongst dried animal matter. Some are predaceous on other insects. The larvæ are also predaceous and very active, many species preying on the larvæ of wood-boring insects, particularly the Anobiids and Scolytids, entering the burrows to reach them. The larvæ of *Trichodes* are known to destroy the larvæ of various bees. Locust egg-masses also are parasitized by some species.

The family has been monographed by Schenkling in the *Genera Insectorum*, Fasc. 13 (1903); it has been listed in the

Berlin Catalogue. There are only nine British species as described by Fowler.

Necrobia rufipes is said to be destructive to dry animal matter in houses, and *N. ruficollis* attacks dried fish in India.

Lymexylonidæ.

Elongate. Antennæ long, serrate or sub-filiform, eleven-jointed. Legs slender ; tarsi five-jointed, filiform, first and fifth joints longest. Integument soft.

A family of from thirty to forty species occurring in most parts of the world.

They are elongate, narrow insects, in colour black or brown testaceous. Some species exhibit a most abnormal form of Coleoptera.

The head is of moderate size ; the short antennæ are inserted on the sides and are usually sub-filiform in the male and serrate in the female. The maxillary palpi of the male are curious, being large and flagellate. The legs are of moderate length and slender, with the tarsi longer than the tibiæ. The elytra of most species more or less cover the abdomen ; but in the genus *Atractocerus* they are very truncate, the large wings not being folded, but extending out on each side. Usually there are six visible sternites ; the species of *Atractocerus* have eight. The integument generally is soft.

The larvæ are curious in having the prothoracic segment enlarged and raised into a sort of hump. The last segment in some species has a long, pointed process, and in others a curious lobe-like structure.

Both larvæ and adults frequent timber, boring cylindrical tunnels through the wood. *Lymexylon navale* has been known to damage ships' timbers in this way, and is found in piles in water.

Lameere has done some work of note on this family, which has been listed in the Berlin Catalogue.

There are two British species.

The family is not of economic importance.

Anobiidæ (*Ptinidæ*).

Antennæ nine- to eleven-jointed, often with feeble, three-jointed club. Tarsi five-jointed, first joint longer than the second. Head retractile into prothorax.

A family of some 1,400 widely distributed species, some species being almost cosmopolitan. In some classifications the *Anobiidæ* and *Ptinidæ* are placed as separate families; but it is difficult to say where the distinction lies.

They are all small beetles, but vary somewhat in shape, from oval-oblong to cylindrical and globular. The majority are obscurely coloured and pubescent; others are glabrous and shining.

The antennæ are variable, being long and filiform and inserted on the frons in the Ptinids, and shorter, serrate, or sometimes feebly clubbed, and inserted on the margins of the eyes in the Anobiids. The head is in many cases retractile into the prothorax; but in some species it is broader than the thorax. The elytra cover the abdomen, which has five visible ventral segments. The legs are long, with five-jointed tarsi.

The larvæ of both groups have much the same appearance, and are small, whitish, fleshy grubs, with curved bodies, causing them to resemble Lamellicorn larvæ. They have short antennæ and three pairs of short legs. The habits of many of the larvæ are of economic interest inasmuch as they bore into timber, furniture, and devour dried farinaceous matter, books, drugs, tobacco, etc. They bore long tunnels, doing much damage, and pupate in cocoons in the tunnels. The larvæ and adults of many species live in decaying wood, while others are found among seeds or in vegetable or animal matter.

Pic lists the species of the *Anobiidæ* and the *Ptinidæ* as separate families in the Berlin Catalogue.

The thirty-one British species are dealt with by Fowler.

Among the *Anobiids* there are several of economic importance. *Anobium striatum* is the well-known "death watch" beetle which lives in old furniture and makes the clicking noise which has given rise to various superstitions. *A.*

paniceum is a cosmopolitan insect occurring in bread, biscuits, and occasionally in skins. *Xestobium tessellatum* does serious damage by honeycombing the beams and rafters of old buildings. *Lasioderma testacea*, in both larval and adult stages, does much damage to cured tobacco in all forms.

Bostrychidæ.

Cylindrical. Head usually deflexed, covered by the hood-shaped pronotum. Antennæ eleven-jointed, with three-jointed club. Tarsi five-jointed, basal joint small, second and fifth long. Tibial spurs distinct. Five equal visible sternites.

Some 200 species are contained in this family, which has a wide distribution throughout the world.

In size the species vary greatly, for although the majority are somewhat small insects, others are known to attain the length of two inches. They resemble the *Scolytidæ*, being oblong and cylindrical in form. Their colouring is dull black or dark brown. Some species are slightly pubescent.

The head is, in nearly all cases, deflexed, and covered by the curious, hood-shaped pronotum. The antennæ are short, with a three-jointed club, but are not elbowed. The mouth-parts are well developed, with strong mandibles. In some species the front of the pronotum is toothed or roughened. The apex of the abdomen in some cases is rounded; but in others it terminates in a flat slope on which are hard tubercles. The legs are short, with the femur and tibia somewhat broadened. The tibiæ bear distinct spines. The tarsi are five-jointed, the first joint being small and in some cases very minute.

The larvæ are soft and white, tapering slightly towards the apex, which is curled round underneath. They have strong mandibles and well-developed legs, which last is a feature absent in the Scolytid larvæ. Eyes are wanting.

Both larvæ and adults live in wood, boring tunnels and feeding on the wood. The larvæ pupate in the tunnels, but do not make a cocoon. The length of the life-history varies according to climate, as many as three broods a year being gone through in tropical regions.

The beetles are subject to attack from other beetles, which seek them out in their tunnels. Some species of Histerids and Clerids are foremost among the attackers : a Colydiid has also been known to prey on them.

The family has been monographed by Lesne, 1903.

Fowler lists the three British species, one of which occurs in old flour, biscuits, and casks, etc., probably having been imported. The other two are extremely rare.

Several of these beetles are serious pests, inasmuch as they attack cut timber and dried wood. Considerable damage is done by bamboo-boring species in the tropics. *Rhizopertha pusilla*, an almost cosmopolitan species, is a household pest in grain, biscuits, etc. The other genera containing economic species are : *Apate*, which attacks the Avocado Pear ; *Xylopertha*, which attacks cacao and fig ; *Bostrichus*, pests of vine and orange ; and *Sinoxylon* in apple, peach, etc.

Lyctidæ.

Like Bostrychidæ ; but club of antennæ two-jointed. First sternite elongate.

This is a small but widely distributed family.

They are narrow, elongate insects, somewhat depressed on the upper surface. Their colouring is dark brown, yellowish brown, or blackish.

They are closely related to the *Bostrychidæ*, but differ in having a two-jointed antennal club, and the first ventral segment of the abdomen elongate. The head is of moderate size, the eyes are prominent, and the antennæ are short, with the club only two-jointed. The mandibles are well developed. The elytra completely cover the abdomen. The legs are slender with five-jointed tarsi, which, like the Bostrychids, have the first joint very small. There are distinct tibial spurs. The upper surface is more or less pubescent.

Altson has recently published work on *Lyctus*, and has shown that in development only part of the egg is absorbed, the larva eating the balance of the yolk as its first meal.

The larvæ are very similar to those of the Bostrychids. They

live in wood, particularly old stumps, posts, etc., and are also often found in both freshly cut and worked timber, especially hard woods such as mahogany and walnut. They enter the timber by one of the worked ends and tunnel some distance in, leaving the tunnels blocked up behind them. In this country only one brood a year is gone through. Lameere has done some work on this family. Fowler lists the two British species.

These beetles often do serious damage to stored and worked timber, such as posts and beams, and the handles of shovels, picks, etc. They are considered to be some of the most harmful of timber pests.

Sphindidæ.

Minute. Oblong or globular. Antennæ ten-jointed, first two joints thickened, last joints forming elongate club. Tarsi heteromerous. Five free visible sternites, the first largest.

A family of only a very few species found in North America and Europe.

They are very small obscurely coloured beetles, oblong and somewhat cylindrical in shape, in general appearance resembling the *Cioidæ*.

They have rather short heads produced in front of the eyes and bearing antennæ which have an elongate club formed by the last three segments. The eyes are somewhat prominent. The elytra completely cover the abdomen. The legs are slender and of moderate length, with five-jointed tarsi on the front and middle legs and four-jointed in most cases on the hind pair, this being a characteristic, separating from the *Cioidæ*.

The larvæ are elongate with short legs and short antennæ. The segments bear lateral hairs. The pupa of *Sphindus dubius* has a long, narrow, tail-like process. Both stages are found in powdery fungi on trees.

Horn has done some work on this family.

There is only one British species, the above-mentioned *Sphindus dubius*.

Cioidæ.

Minute. Cylindrical. Antennæ eight- to ten-jointed, with three-jointed club. Tarsi usually four-jointed, the first small and the last long.

A widely distributed family of between 200 to 300 species. They are cylindrical and very small, generally dark brown or yellowish in colour.

The head and anterior portion of the thorax of the males is often furnished with small, horn-like processes. The antennæ are inserted under the margins of the forehead. The elytra completely cover the abdomen. The legs are rather short; the last joint of the tarsi is much longer than the first three together. Generally the thorax and elytra are pubescent.

The larvæ are white, cylindrical and somewhat curved, the last segment bearing a pair of short hooks and also a short process acting as a pro-leg. The thoracic legs are long. The pupa also possesses the curved apical spines.

Both larvæ and adults live in corky fungous growths or in decaying, fungoid wood.

A list of the species can be found in the Berlin Catalogue, Part 30. Fowler deals with twenty-one British species.

Buprestidæ.

Mostly brilliantly metallic. Head short, vertical. Antennæ short, serrate, eleven-jointed. Tarsi five-jointed, basal four with pads. Prosternum produced back into mesosternum. First two sternites connate.

A large family of some 5,000 species, widely distributed throughout the world, by far the greater number, however, occurring in tropical regions, the smaller and less conspicuous being found in temperate countries.

They are all elongate insects, broadest across the base of the abdomen and tapering slightly towards the apex. They vary much in size, some being less than a quarter of an inch, while many are as much as two inches long and of robust build. The colouring in the majority of cases, and especially in the larger

forms, is very conspicuous, being brilliantly metallic, ranging from bronze-black to beautiful greens and blues. Some species have spots or bands of a different colour; but true warning coloration is not noticed in this family. The venter of many of these beetles is also brilliantly coloured.

The head is short, vertical, and sunk into the thorax as far as the eyes. The mouth-parts are short and of the herbivorous type. The antennæ, which are inserted on the front, are serrate and rather short. The thorax closely joins the abdomen, which is completely covered by the well-fitting elytra. The prosternum is prolonged into a process behind, fitting into a mesosternal cavity. The legs are short, with five-jointed tarsi, the first four joints having membranous pads beneath: the legs are concealed under the body when not in use. The wings are large and often used. The elytra of some species are smooth, of others deeply sculptured. There is not much difference in the external appearance of the males and females.

The larvæ are very curious in form: the head is very small, with very short antennæ and short, strong mandibles. The thoracic segments, especially the prothorax, are greatly enlarged, having a swollen appearance. The abdomen, consisting of nine segments, is long and narrow. The legs are either very rudimentary or totally absent. These larvæ live under bark or make borings in wood and plant stems, or mine in leaves. The swollen nature of the thorax is brought into use as leverage to aid the larva in its progress along the borings. Pupation takes place in the bore, which is closed by debris, no actual cocoon being formed.

The length of the life-history varies, some of the large species taking one year to go completely through, while some of the smaller species may have several broods during the year. They have been found in hibernation both as adults and larvæ. There are several Hymenopterous parasites.

The family has been monographed by Kerremans in *Genera Insectorum*, Fasc. 12 (1903). There is also a good deal of economic literature.

The ten British species are listed by Fowler.

There are a considerable number of species of economic importance as pests of plants like cotton, jute, groundnut; fruit trees such as mango, guava, orange, apple, pear, cherry,

and plum, and also various bush fruits. Much damage is often done to forest trees. Genera containing species of economic interest are: *Agrilus*, *Belionota*, *Catoxantha*, *Chrysobothris*, *Buprestis* (*Dicerca*), *Sphenoptera* and *Stigmodera*.

Elateridæ.

Click beetles.

Antennæ filiform, serrate or pectinate. Tarsi five-jointed. Legs retractile. Prothorax with hind angles produced backwards. Prosternum produced back into mesosternum. First two sternites not connate.

This is a large and well-known family containing from two to three thousand very widely distributed species. Several authors have thought it reasonable to place some of the various sub-families as separate families; but as they have so many characters in common it is justifiable to class them all under one heading.

Fig. 48.—*Elater lythropterus.* (× 4.)

They do not show much variation of form, all being more or less elongate, narrow and somewhat depressed. They range from quite small insects to ones over an inch in length and of robust build. In many cases, especially among the larger forms, they are brightly coloured; others are brown or yellowish in tint, and many are entirely black.

The head is small, somewhat sunk into the prothorax and bearing mandibles, bifid at apex; round, but not very prominent eyes, and antennæ of moderate length, which are in some cases filiform, and in others serrate or pectinate. The prothorax is large, with the hind angles produced sharply backward, more strongly in some species than in others. The prosternum is produced into a spine-like structure behind, fitting into a cavity in the mesosternum. It is this structure

which gives the power of leaping, accompanied by a sharp clicking sound, possessed by many of these beetles: hence the name of "click beetles" as popularly applied to them. The mesosternum is short and the metasternum is, as a rule, long. There are five visible ventral segments. The elytra are neatly adapted and with few exceptions completely cover the abdomen. A few females are known in which the elytra are slightly abbreviated. The legs are slender and of varying length, but are never very long; they are often retractile. The tarsi are five-jointed, with simple, toothed or pectinate claws.

The chief sub-families are the *Eucneminæ*, the *Elaterinæ*, the *Cebrioninæ*, the *Perothopinæ* and the *Cerophytinæ*. The last two are made up of one genus each. *Perothopinæ* is considered by some people to be better included with the *Eucneminæ*; but with *Cerophytinæ* can be separated by the fact of the very long trochanters of their middle and posterior legs. The *Eucneminæ* are rather more cylindrical than the rest of the family and many of them possess the above-mentioned power of leaping. Their larvæ, although resembling in many respects the other Elaterid larvæ, are legless, with very rudimentary mouth-parts and antennæ, and have no ocelli. The head bears on its front some very hard, sharp teeth, which presumably aid the larva to bore into the soft, rotting wood in which it lives. Judging by the form of what little mouth-parts it has, its food is very possibly the juices of the rotting wood.

Among the *Elaterinæ* are many of the largest forms known, including the *Pyrophorinæ*, occurring in the tropics, and to which the name "fire-flies" have been given, owing to a light emanating from the two dull yellowish spots near the posterior angles of the thorax. Nearly all the *Elaterinæ* can jump, and are the typical "click beetles." Many of their larvæ are notorious as being the so-called "wire-worms" which do considerable damage to the roots of wheat and other crops of a similar nature. They are elongate and cylindrical, with extremely tough skins, a small head, short thoracic legs and a variable last segment, which may be sinuate at the sides, with the apex simple or divided into a pair of toothed processes. In the adults of some of the big species (*Alaus*) there are on the pronotum large, round markings like bright eyes. All of them cannot be denounced as crop pests, as many species live

in decaying wood, and others are carnivorous. Many of them remain as larvæ for a considerable period, sometimes several years.

The *Cebrioninæ* are least of all like the rest of the family, and some of them are more like Lamellicorns. They do not possess the power of jumping, their legs being more of the digging type, with well-developed tibial spurs. Their larval stage is passed in the ground from which the winged males emerge in due season; but the females are wingless and remain in the ground, with only the posterior end of their bodies protruding. The larvæ have no anal processes and their anterior legs are shortened.

The adults of the *Elateridæ*, in general, occur in many situations: in grass, on flowers and foliage, in rotting wood, or under bark. Many only appear at night, while others are diurnal of habit.

Schwarz has monographed the family in *Genera Insectorum*, Fasc. 46 (1906), with the exception of the *Cebrioninæ*, which has been monographed in Fasc. 127 (1912) as a separate family by Dalla Torre, who also lists the species in the Berlin Catalogue. Candeze has described many species, particularly the Indian ones.

Fowler lists the sixty-two British species.

Some species of the *Elaterinæ* are of economic importance, owing to their larvæ, the well-known "wire-worms" being destructive to the roots of wheat and similar crops. These species are contained in the following genera: *Agriotes*, *Athous*, *Limonius* and *Melanotus*. The only known method of control is to plough in a crop of mustard before sowing the cereal crop, and they are not usually pests of cultivated land, but of newly broken pasture.

Throscidæ (*Trixagidæ*).

Very small. Prothorax closely articulated with mesothorax. Front coxal cavities closed behind by mesosternum. General appearance otherwise like Elateridæ.

A small family containing about 150 species, mostly occurring in Europe and America, in which countries they are widely distributed. A few species are found in tropical regions.

In general appearance these beetles resemble the Elaterids. They are very small, seldom exceeding 3 mm. in length, and are usually somewhat obscurely coloured.

The head is sunk into the thorax as far as the eyes, which are hairy and emarginate. The antennæ are inserted on the front and can be concealed in grooves beneath. They are usually serrate; but in some species may have a loose, three-jointed club. The thorax is closely applied to the abdomen, which is completely covered by the elytra. The prosternum has a flat elongation behind, fitting into a groove in the mesosternum. There are five visible ventral segments; but the first two are not connate as in the *Elateridæ*. The legs are short and retractile, the tarsi five-jointed with one or more joints having a membranous lobe beneath. These beetles do not possess the power of jumping.

Little seems to be known of the life-history. The adults are found at the roots of grass, in vegetable refuse and dead wood or on plants. Fowler has listed the four British species.

(*d*) HETEROMERA.

Anterior tarsi five-jointed, hind tarsi four-jointed.

Tenebrionidæ.

Antennæ under a projection at the side of the head. Tarsal claws simple. Five visible sternites.

This is a huge family containing well over 10,000 species. They have a wide distribution, and are perhaps most abundant in the North African and Mediterranean regions.

The great majority of them are ground-living insects of sombre colour and varying size, some being only a few millimetres, while others are nearly two inches long, and of robust build. The head is of moderate size, with strong mandibles of the herbivorous type. The antennæ are short, eleven-jointed and of variable form. The whole body is of compact build and somewhat hard. The elytra are close-fitting, and in many cases soldered together, wings being absent, or

practically so. Some species have large wings. The legs are of moderate length and enable some species to move with great speed. In a few cases the males have erect horns on the head, but to what use they are put, is unknown. Other males may be distinguished by the presence of a tuft of hair on the abdomen, or the dilation of the tarsi.

The larvæ, which greatly resemble one another, are elongate and cylindrical, with brown, leathery integument. The apical segment of the abdomen bears two hooks and a short, retractile process. The thoracic legs are of moderate length. The pupæ are rather broad compared with the larvæ, and bear two short cerci and a series of projections from the sides of the abdomen. The majority of the larvæ and adults only appear at night, and act as scavengers, feeding on vegetable waste. They prefer dry situations and are frequently found in sandy places, and are abundant in desert areas. Loose bark, thatched roofs, fallen leaves, etc., are the sort of places which afford shelter for these beetles. Some species live in houses: for instance, the big, dull-black beetle belonging to the genus *Blaps*, and known in this country as the "cellar beetle." *Tenebrio molitor*, the cosmopolitan "meal beetle" and its larva the "meal worm," infest granaries, feeding on the stored grain and flour: sometimes doing considerable damage.

FIG. 49.—*Helops striatus* (*Tenebrionidæ*) (3½ times nat. size).

A number of species show themselves during the day, and a few are more brightly coloured. Gebien lists the family in the Berlin Catalogue.

Schiödte has figured the larvæ and pupæ of several species. There are thirty British species, listed by Fowler.

As well as the grain-infesting *Tenebrio molitor*, a few other species have proved themselves to be injurious: the adults and larvæ of some species of the genus *Opatrum* attack the roots and shoots of potatoes, grain and groundnut. Other

genera containing species of economic interest are: *Eleodes* and *Omophlus*, which attack cereals, and *Holaniaria*, attacking cane; to some extent these genera and *Opatrum* replace in the tropics the wire-worm pests (*Elateridæ*) of temperate regions. *Tribolium* includes species found commonly in stored grain, flour, etc.; it is very widespread, probably quite harmless to grain, in which it may occur abundantly.

ÆGIALITIDÆ.

Head prominent. Eyes small. Six visible sternites. Tarsi, with exception of last joint, pubescent beneath. Claws simple.

This family is comprised of four species found in Alaska and California.

It is thought by some authors that these beetles should be included with the *Tenebrionidæ*; others have considered placing them with the *Dryopidæ* or *Pythidæ*.

They are small insects. The head is prominent and the eyes are small. The eleven-jointed antennæ are inserted under small ridges on the front. There are six visible, ventral segments, the last one only having the tip showing. The coxæ are all widely separated. The tarsi, with the exception of the last joint, are pubescent beneath.

The earlier stages are not yet known.

There is a list of the species by Brochmann in the Berlin Catalogue.

LAGRIIDÆ.

Prothorax cylindrical, narrower than base of elytra. Anterior coxæ projecting, conical and contiguous; cavities closed behind. Five visible sternites. Legs slender, claws simple, penultimate tarsal joint bilobed, pubescent.

This family is allied to the *Tenebrionidæ* and contains about 550 widely distributed species.

They are insects of moderate size, resembling in general characters many of the Tenebrionids, and are mostly of some inconspicuous colour.

The antennæ are filiform and inserted on the front under small ridges. In some species the males have the head broader than that of the female. The prothorax is somewhat cylindrical and is narrower than the base of the elytra, which completely covers the abdomen and is in many cases of a somewhat flexible nature and rounded at apex. The legs are slender and rather long. The anterior coxæ differ from those of the Tenebrionids in being conical, contiguous and projecting. The coxal cavities are closed behind. The penultimate joint of all tarsi is bilobed and pubescent beneath. The body generally is hairy.

The larvæ are very like those of the Tenebrionids, but are usually somewhat broader. The larva of *Lagria hirta*, a British species, has been described by Schiödte as being moderately broad and parallel-sided, with a small, short head and the last abdominal segment slightly bifid at apex. The legs are rather long. The pupa, as also described by Schiödte, is moderately long, with a broad, clavate process projecting from the sides of the abdominal segments, with the exception of the two last.

The adults are found on foliage, in hedges, and sometimes under bark. The larvæ live in soft, rotting wood, or under dead leaves, and are more active than those of the *Tenebrionidæ*.

Borchmann has listed the family in the Berlin Catalogue. *Lagria hirta* is the only British species.

Othniidæ.

Elongate. Antennæ eleven-jointed, last three joints forming loose club. Head large, flat. Apex of abdomen exposed. Five visible sternites. Legs slender.

This is another family of doubtful position, it being thought by some authors to belong to the lower forms of the *Tenebrionidæ*. There is only one genus, made up of sixteen species, occurring in Borneo, New Guinea, India, Ceylon, Japan, and Central Africa.

They are elongate insects, with large, flat heads and loosely clubbed antennæ. The elytra leave the apex of the abdomen exposed. The legs are slender. The integument generally is weak.

The earlier stages are unknown. The adults have been found on foliage, and are in all probability predaceous.

The species are listed by Borchmann in the Berlin Catalogue.

Cistelidæ (*Alleculidæ*).

Like Tenebrionidæ; but tarsal claws pectinate.

A family of over 1,000 species, all closely allied to the *Tenebrionidæ*, widely distributed, but mostly in temperate regions.

They are usually oblong-oval in shape and of moderate size, with a fairly wide range of markings and coloration, some being plain black or brown and others brighter, with various spots or splashes.

The only real structural difference between them and the *Tenebrionidæ* is the fact of their having the tarsal claws pectinate instead of simple. The antennæ are long and of greater length in the male, which also has bigger eyes.

The larva of one species, *Cistela ceramboides*, is described by Westwood as being long, subcylindrical and scaly, with short, three-jointed antennæ, and having the last abdominal segment conical and without cerci or processes. The larvæ, generally, are found in decaying trees or under bark. The adults also occur under bark or in soft wood, but are sometimes found on flowers.

A complete list of the family by Borchmann will be found in Part 3 of the Berlin Catalogue.

There are seven British species.

No member of this family is of importance economically.

Monommidæ.

Small, oval. Antennæ eleven-jointed, with three-jointed club, received in grooves on prosternum. Head horizontal, prominent. Legs strongly retractile. Tarsi slightly pubescent beneath.

This family, which is made up of two genera, contains something over a hundred species. The majority of one genus occur in Madagascar, while the other is confined to the New World. One species is found in India.

They are small insects, oval in form and generally of dull colouring.

The head is horizontal and somewhat prominent. The antennæ, which have a three-jointed club, are received into grooves in the sternum. The legs are capable of being retracted and the tarsi are slightly pubescent beneath.

The adults have been found under the bark of trees, where it is presumed they feed on the sap-wood.

The family has been monographed by Thomson (1860).

Nilionidæ.

Hemispherical, resembling Coccinellidæ. Head vertical. Prothorax leaf-like at the sides. Anterior coxal cavities apparently open behind. Tarsi filiform ; claws simple.

The members of this family, which number from twenty to thirty species, occur in Central and Tropical America.

In general appearance they resemble the *Coccinellidæ*, being hemispherical. They are of moderate size.

The head is vertical, and when in repose rests against the anterior coxæ. The antennæ are eleven-jointed, and inserted in front of the eyes. The prothorax is curiously leaf-like at the sides. There are five visible ventral segments. The anterior coxal cavities, being apparently open behind, is a character separating this family from the *Tenebrionidæ*.

These beetles are said by Lacordaire to be found walking about on fungi on tree-trunks and to feign death on alarm. He also says that they exhale, in common with other bole-saprophagous beetles, a peculiar smell.

The earlier stages are not known.

Borchmann lists the family in the Berlin Catalogue.

Petriidæ.

Elongate, slender. Antennæ long, filiform, eleven-jointed. Anterior coxal cavities almost closed behind. Elytra dehiscent, not reaching apex of abdomen. Legs and tarsi long and slender ; claws simple.

A family of but few species occurring in the Transcaspian region.

They are elongate, narrow, weak-looking insects, somewhat resembling certain of the *Cerambycidæ*. The head is rather narrow and the thorax slightly cylindrical; the elytra leave the apex of the abdomen exposed and are more or less dehiscent. The wings are large. The legs are long and slender, with simple tarsi, a point in which they differ from their allies, the *Œdemeridæ*, which have the penultimate tarsal joint dilated.

Of their habits and life-history nothing appears to be known.

The species have been listed by Borchmann in the Berlin Catalogue.

Œdemeridæ.

Elongate, slender. Delicate integument. Head narrowed behind, produced in front into a short rostrum. Antennæ usually filiform. Prothorax narrowed. Penultimate tarsal joint bilobed, claws simple. Anterior coxal cavities wide open behind.

This is a family of about 600 species, widely distributed in both temperate and tropical countries.

They are elongate, narrow insects of moderate size, often brightly coloured and with a somewhat delicate integument. They have a superficial resemblance to both Cerambycids and Malacodermids.

The head is large, bent slightly downwards, produced into a rostrum in front and narrowed behind the eyes, which are in some cases very large. The mandibles are flattened. The antennæ are long, very long in some species, generally filiform, but occasionally serrate. The thorax is narrower at the base than the elytra, which in nearly all cases completely cover the abdomen and have more or less strongly raised lines. There are five, free, ventral abdominal segments; some males have a sixth visible. The legs are moderately long, with the femora in the males of some species thickened into a knob, and the tibia curved. The penultimate joint of the tarsi is bilobed.

The larvæ and pupæ of some species have been described by Schiödte. That of *Œdemera virescens* is elongate and narrow, with a large head and the prothoracic segment larger than the other segments. The apex of the abdomen is rounded and simple. The legs are rather long. The pupa is long and

has a prominence on each side of the anterior portion of the thorax, and also possesses two short, curved cerci. The larvæ generally feed on decaying wood ; that of *Nacerdes melanura*, a British species, lives in piles driven in the sand of the seashore, and in old palings and decaying timber. The majority of the adults frequent flowers and herbage, while a few are said to be more often found on the ground near water. The family has been listed by Schenkling in the Berlin Catalogue. There are seven British species, which are listed by Fowler. The family does not contain any species of real economic importance.

Pythidæ.

Head not constricted behind, sometimes produced into a rostrum. Prothorax narrowed at base. Elytra cover abdomen. Tarsi slender.

This family contains about 100 species, the majority of which occur in temperate regions ; a few are found in Chili, Madagascar, New Guinea, etc.

They range from small to moderate size and are variable in shape, some species being elongate and much depressed, while others are more quadrate. Bright colouring is seen in many species, but several are of sombre appearance. Several authors consider them to belong to the *Melandryidæ* ; but the fact of the pronotum being narrowed at the base, and the front of the head being sometimes produced into a rostrum, separates them from that family.

The head is prominent and not constricted behind. The antennæ are either filiform or have a slight thickening towards the apex. The thorax, as mentioned above, is narrowed at the base, while the elytra completely cover the abdomen and are rounded at apex. The legs are slender and of moderate length, with the tibiæ bearing small spurs. There are five free ventral segments.

The larva of *Pytho depressus*, a British species, is described by Fowler as being elongate, parallel-sided and glabrous, with a large, semicircular head ; the thoracic and abdominal segments of the same size and having a deep furrow running down the centre of all except the last, which narrows slightly and bears

a pair of strong, incurved processes. This larva occurs under the bark of fir and pine. In some other species the larvæ have a few hairs scattered about the integument. The adults are found under bark, in dead twigs, on flowers, especially umbelliferous, and some species under stones. The larvæ live under bark, in twigs, or in the stems and roots of plants.

Fowler lists the eleven British species.

Melandryidæ.

Head usually deflexed, not constricted behind eyes. Antennæ usually filiform, eleven-jointed. Prothorax broad behind. Legs slender; claws simple.

This family contains about 200 species, nearly all of which are found in cold or temperate regions, very few being recorded from hot countries.

They are from small to moderate-sized beetles, usually elongate and rather narrow, but varying somewhat in shape. They are dull of colour.

The head is usually bent downwards and sunk into the prothorax as far as the eyes. The mandibles are rather short. The antennæ are usually filiform, eleven-jointed, except in the genus *Conopalpus*, in which they are only ten-jointed. The thorax does not narrow at the base. The elytra completely cover the abdomen, which has five visible ventral segments. The legs are rather long and slender, with the claws simple.

The larvæ vary in form: that of *Orchesia micans*, a British species, is elongate and linear, with the head, legs and dorsum of thorax corneous. The head is rather large, but not as broad as the prothorax. The apical segment is narrower than the rest and does not bear any appendages. The pupa has the prothoracic shield dilated on each side, and at the apex of the abdomen has a bunch of rather sharp, slightly curved protuberances. The larvæ of *Melandrya* are elongate and cylindrical, with a very large head, and the prothoracic segment larger than any of the others. The larvæ of some other species have the last segment furnished with a pair of horny appendages.

With the exception of one genus (*Osphya*), both larvæ and

adults live in rotting timber, fungi, or under loose bark. *Osphya* is found on flowers. There are twenty-one British species, listed by Fowler.

Scraptiidæ.

Small, delicate. Head raised, strongly constricted behind eyes. Antennæ filiform. Eyes emarginate. Posterior tibiæ as long as tarsi. Penultimate tarsal joint bilobed.

This is a family of rather doubtful position: some authors placing it with the *Melandryidæ*, while others consider it to be more allied to the *Mordellidæ*. It contains about eighty species, the majority of which occur in Europe and North America; one has been found in Ceylon and three or four in Chili. All are as a rule somewhat scarce.

They are small, delicate-looking insects, elongate and rather narrow, of dull colouring and usually pubescent.

The head is much constricted behind the eyes and is raised higher than the prothorax. The eyes are emarginate and the antennæ filiform. The anterior coxal cavities are open behind and the posterior tibiæ are as long as the tarsi, all of which have the penultimate joint bilobed.

The larva of *Scraptia fuscula*, as described by Perris, is elongate and linear, with the last abdominal segment very long and covered with long, fine setæ, but not bearing any processes. Both larvæ and adults live in rotting wood or tough tree-fungi. It is considered very probable that *Scraptia fuscula* is to a certain extent myrmecophilous in both larval and adult stages.

A list of the family will be found in the Berlin Catalogue. Two species only occur in Britain and are dealt with by Fowler.

Mordellidæ.

Head vertical, ridged behind; neck very small. Antennæ eleven-jointed, filiform. Posterior tibiæ shorter than tarsi. Penultimate tarsal joint simple. Hind coxæ laminate.

Over 700 species are contained in this family, some of them very widely distributed, while others are found chiefly in Europe and North America.

They are small, with elongate, narrow, convex and somewhat arched bodies. Most of them are black and covered with a silky pubescence. The head is vertical and very strongly constricted behind the eyes. The thorax is as wide at base as the elytra, which narrow behind and leave the tip of the abdomen exposed. There are five or six ventral abdominal segments, the apical one often being produced into a strong style. The legs are slender, with the posterior coxæ laminate and the posterior tarsi nearly twice the length of the tibiæ, which bear long spines. Many species have the power of leaping, which is attributed to the formation of the tibiæ and tarsi and the presence of the apical style.

The larvæ of some species are elongate and curved, with protuberances on the first few abdominal segments: these protuberances are also present in the pupæ. The form of the anal segment in the larva varies: in some cases bearing a strong style, and in others being deeply cleft.

The majority of the adults frequent flowers, low trees or shrubs: some, however, are found in decaying wood. The larvæ of some species also live in rotting wood, where they have been found on occasion in the tunnels of xylophagous insects. Others live, and presumably feed, in the stems of plants. It is thought that a few species may be carnivorous, but as yet there is no definite proof.

The family has been listed by Csiki in the Berlin Catalogue. Fowler deals with the nineteen British species. A species of *Mordellistena* is said to be injurious to sunflowers in Russia.

Rhipiphoridæ.

Humpbacked. Head vertical, resting against fore coxæ. Antennæ variable, flabellate or sub-serrate. Prothorax as broad at base as elytra, which are often dehiscent. Claws variable, pectinate, or toothed.

This family is a small one of about 230 species. They are widely distributed throughout the greater portion of the world, the temperate regions having the majority of the species.

They are very closely allied to the *Mordellidæ*, from which family they are separated by rather indefinite characters.

They are all narrow and elongate in shape and are usually of dull colouring.

The head is vertical and sharply constricted behind the eyes. The antennæ are variable in shape and differ in the sexes, being flabellate or pectinate in the males and serrate in many cases in the females. The thorax is as broad at the base as the elytra, and is often produced at the base into a lobe covering the scutellum. The elytra are narrow and pointed at the apex, and are in many cases strongly dehiscent, leaving the apical portion of the wings and abdomen exposed. The number of free ventral segments varies. The legs are long, with distinct tibial spurs, and toothed or pectinate claws.

The life-histories of some of these beetles are very interesting inasmuch as many of the larvæ are parasitic on wasps, and in one case on cockroaches. The larva of *Metœcus paradoxus*, the one British species, is in its early stages very similar to the Meloid larvæ. There seems to be some doubt as to how the young larvæ gain access to the wasps' nests : whether the adult lays the eggs in the dead wood from which the wasps obtain their nesting material, and they thus get carried into the nest with the shavings, or whether the larvæ hatch out first and attach themselves to the foraging wasps, remains a question. Having by some means reached a cell in the nest, the larva attacks the occupier and eats into its interior, where it feeds for some time and grows considerably. Later it emerges from the grub and moults, changing much in form ; it then continues to feed, and undergoes another moult, after which it completely finishes its victim and pupates in the cell, emerging as a beetle soon after. When full grown the larva is about 11 mm. long, and resembles a *Crabro* larva, being whitish, flattened in front, with a small head and the last two segments smaller than the rest, the apical one cleft and bearing an anal tubercle. The adults may occasionally be found on flowers. One species undergoes its larval stage in the root and stem of a plant (*Eryngium campestri*) and pupates in a cocoon formed on the outside of the stem.

The species (*Rhipiphorus pectinicornis*) parasitic on cockroaches is wingless and larviform in the female, who never leaves the body of her cockroach host.

An interesting account of *Metœcus paradoxus* has been

written by Chapman (1891). *Emenadia* has been secured from the nests of the potter wasp (*Eumenes*) in India.

The species have been listed by Csiki in the Berlin Catalogue. There is only one British species.

Meloidæ (including *Lyttidæ*—formerly *Cantharidæ*).

Head vertical, constricted with abrupt neck. Prothorax at base plainly narrower than elytra. Tarsal claws with closely applied appendage beneath. Integument usually soft.

This is a large family containing nearly 2,000 widely distributed species.

They are of moderate size, generally from half an inch to an inch long. They are usually of fairly robust build. Some have warning coloration, others are metallic blue or green, while others again are dull brown or black.

The head is of moderate size, placed vertically, and joined to the thorax by a distinct neck. The antennæ are usually eleven-jointed and simple. The eyes are large. The mouth-parts are not prominent and not very strong. The thorax is not as broad as the abdomen. The elytra are generally weak, loosely fitting, and do not meet down the whole length of the median line, in some cases being widely dehiscent. There are six visible ventral segments. The majority of these beetles possess functional wings; but the species of the genus *Meloë* are wingless. The legs are long, with long tarsi, and claws which have a closely fitting appendage beneath. The anterior and middle coxæ are large and contiguous.

The earlier stages of these beetles are very curious and have given rise to much discussion. Masses of small yellow eggs are deposited on grass or on the bare earth. They hatch and little triungulin larvæ emerge. These, in some cases, run about until they come across the egg-mass of a locust, into which they force their way and devour the eggs. Between the triungulin larvæ and the adult insects there are a series of curious stages. The egg yields an active triungulin, which at the moult loses its legs and becomes scarabeoid: it then

becomes a "propupa," and later a normal pupa. Other species are parasitic in the nests of various bees, going through the same curious metamorphosis. The young triungulin larvæ, after emerging from the egg on the ground, gain access to the bee's nests by attaching themselves to bees and getting carried there. Fabre gives an interesting account of the *Sitaris* which spend their early stages in the nests of bees belonging to the genus *Anthophora*. Riley gives an account, quoted by Sharp in the *Cambridge Natural History*, of the life of *Epicauta*, which infests the egg-masses of locusts.

The adults are herbivorous and may be seen during the day on flowers and foliage. The species of *Meloë* are more often found crawling on the ground. These beetles have a habit of appearing in greater abundance in some years than in others.

Borchmann has listed the species in the Berlin Catalogue. Marseul has monographed the sub-family *Mylabrinæ*. There are nine British species.

The adults of a few species belonging to the genus *Epicauta*, when abundant, are destructive to cereal crops, by eating the stigma and anthers, so that the grain cannot form. In America, *Epicauta pennsylvanica* eats the leaves of potato and beet. *Mylabris* are pests of pulse. These beetles are the "Blister-Flies" of medicine, owing to their content of cantharidin: they are still in use, though synthetic cantharidin is now replacing them.

Pyrochroidæ.

Head exserted, constricted behind eyes, which are emarginate. Antennæ flabellate or pectinate. Prothorax narrower than elytra, which are wider than abdomen. Legs long; penultimate tarsal joint bilobed; claws simple.

About sixty species are contained in this family; the majority of them inhabit temperate or cold countries: North Europe, Siberia, Japan, and North America. A few have been found in India and Burma.

They are allied to the *Melandryidæ*; but the formation

of the head and neck, and the bilobed penultimate tarsal joint, are characters which clearly separate them from that family. The majority of them are moderately large, conspicuous insects, usually with a colour scheme of bright scarlet and black, the head and thorax sometimes being black and the elytra scarlet, or vice versa. The head is conspicuous and constricted at a little distance behind the eyes, which are emarginate. The thorax is narrower at base than the elytra, which are rounded at apex and wider than the abdomen. There are five free, ventral segments in the female, a sixth being visible in the male. The legs are long, with the penultimate tarsal joints bilobed and the claws simple.

The larvæ are flat, elongate, parallel-sided, with a large head, short antennæ and palpi as long as the antennæ. The penultimate segment is much longer than the others, while the apical segment is very short and bears two short, upward-projected spines. The legs are short, with one claw. The wings and wing-cases visible in the pupæ are very short. Both larvæ and adults live under bark or in rotting wood; but on hot sunny days the adults may sometimes be found on flowers and shrubs. It is believed that one species, *Pyrochroa coccinea*, takes three years to go through the larval stage. Fowler lists the three British species.

Xylophilidæ.

Like Anthicidæ; but penultimate tarsal joint concealed in lobes of anti-penultimate joint, causing the tarsi to appear four-, four-, three-jointed. First two sternites connate. Posterior coxæ approximate.

Some 300 widely distributed species are contained in this family. Many of them superficially resemble some of the Anobiids, while others are more like *Anthicus*.

The head is sharply constricted behind the eyes, which are large and rather coarsely granulated. The antennæ are long and as a rule filiform. The thorax is much narrower at its base than the elytra. The legs are slender, with small tibial spurs, while the penultimate tarsal joint is completely hidden by the lobes of the preceding joint. The first two sternites

are connate, a character which helps to separate this family from the *Anthicidæ*.

The majority of these insects are found in oak woods at high elevation, where they live in decaying branches, as do presumably the earlier stages. Occasionally in Europe they are found on flowers or in dead hedges.

Pic has listed the species in the Berlin Catalogue.

There are three British species listed by Fowler.

Anthicidæ (*Hylophilidæ*, *Pedilidæ*).

Small, many ant-like. Head with small neck, base of prothorax narrower than elytra. Five free visible sternites. Posterior coxæ separate. Penultimate tarsal joint bilobed, conspicuous.

There are some 1,500 species contained in this family, many of them are very widely distributed, the greater number perhaps occurring in temperate countries.

They are all small and generally dull brown or black in colour and many of them much resemble ants, both in shape and their mode of running about.

The head is large, strongly constricted behind the eyes and joined to the thorax by a short neck. The antennæ are filiform. The thorax is not as wide at its base as the elytra, which in the majority of cases cover the abdomen, but in some species leave the pygidium exposed. The first ventral segment is much longer than the second. The legs are long and slender with the penultimate tarsal joint bilobed and plainly visible. The posterior coxæ are separate.

The earlier stages af these beetles seem to be very little known. The adults are usually found in the ground, often in damp places by ponds, or in salt marshes; some prefer sandy places and others rubbish or manure heaps. During hot weather many species may be seen on herbage, running about in a manner which, together with their general appearance, completes their resemblance to ants.

The family has been listed in the Berlin Catalogue by Pic, and monographed in *Gen. Ins.* Fasc. 8 (1902) by the same author.

Fowler deals with the ten British species.

Species of the genus *Notoxus* are injurious to beet in Europe.

Trictenotomidæ.

Size 2½ to 3 in. Resemble Cerambycidæ. Mandibles strong and projecting. Antennæ long, serrate inside at apex. Prothorax laterally dentate.

This family contains only a few species, confined to the Indian and Indo-Malay regions.

They are fine large insects, sometimes attaining the length of three inches. In general appearance they are very much like *Prionus* of the *Cerambycidæ* and have been placed by some authors in that family; others have classed them with the Lucanids. Most of them have dark, cryptic colouring; but there is one species of metallic blue.

The head is large and horizontal and bears strong, projecting mandibles. The stout, eleven-jointed antennæ are inserted just before the eyes and have the last three joints serrate on the inner side. The thorax is slightly narrower than the elytra and has sharply toothed margins. The elytra are strong and cover the abdomen completely. There are five visible ventral segments. The anterior coxal cavities are open behind and with the exception of the last, all the tarsal joints have at the apex underneath a small tuft of hairs.

A larva is known and has been described by Mr. C. G. Gahan as being over four inches long, parallel-sided, with the segments narrowing in front and behind. The head large, the legs distinct but not long, and the last abdominal segment terminating in two short, bent processes. As a whole it resembles a Pyrochroid on a large scale.

The adults inhabit forest regions and are possibly predaceous. A list of the known species is to be found in the Berlin Catalogue.

(*e*) PHYTOPHAGA

Tarsi five-jointed, apparently four-jointed, the third joint usually thickly pubescent beneath.

LARIIDÆ (*Bruchidæ*).

Pulse beetles.

Small, thick-set. Head free, produced in front. Elytra truncate, pygidium exposed. Hind femora thickened. Antennæ eleven-jointed, dentate or pectinate. First tarsal joint elongate. Claws broadly toothed at base.

About 800 species are contained in this family. They have a wide distribution, having, owing to their habits, been carried about the world by commerce.

They are small, thick-set beetles, sombre in appearance, and have the body clothed with hairs. The head is small and produced in front into a short, blunt rostrum. The antennæ are eleven-jointed and in many cases serrate or pectinate. The well-developed prothorax is closely applied to the mesothorax. The elytra do not entirely cover the abdomen, but leave the pygidium exposed. The abdomen is very thick-set. The legs are somewhat short, with the femora thickened and the first tarsal joint of all the legs elongate.

The eggs are small, oval in shape and yellow of colour. They are laid in an adhesive condition on the seeds or the seed pods of various plants, particularly those of the *Leguminosæ*. The resulting larvæ are white, soft, fleshy grubs, with strong biting mandibles, and in the first instar, very short thoracic legs and a pair of toothed thoracic plates; the legs do not appear in the later stages. Pupation takes place inside the seed, and in this country, at any rate, the beetles remain as pupæ during the winter. The larvæ eat out the inner portion of the seed, but leave the germ unharmed. They are much parasitized by Chalcids. The adults are found on flowers and foliage.

Numerous papers have been written on the economic importance of these beetles. A complete list of the species by Pic will be found in the Berlin Catalogue.

There are thirteen British species.

In this and other countries a great deal of damage is done by species of *Bruchus* to seeds of leguminous crops, both in the field and stored.

Chrysomelidæ.

Antennæ moderately long, or short, their insertion distinct from the eyes. Upper surface bare. Tibial spurs usually absent. Form variable.

This is a widely distributed family made up of a vast number of very variable species. It has been split up into five main divisions: these are:—

I. *Eupodes*, in which the thorax is without distinct lateral margins, the head is produced, the eyes prominent and the prothorax narrow. Three sub-families are contained in this division: the *Sagrinæ*, the *Criocerinæ* and the *Donaciinæ*.

The *Sagrinæ* are large, oblong insects, usually brightly coloured, with the posterior femora much thickened. Little seems to be known of their life-histories. One species is known to lay eggs on the bark of a tree, and the larvæ have been found feeding in roots. The adults are found on plants.

The *Criocerinæ* are from small to moderate size, somewhat oblong in shape and showing a variety of colours, in some species warning. They live on plants and grass. Their larvæ are short, oval and convex, and are usually dark-coloured. In many cases the larvæ are semi-aquatic and live on the leaves of aquatic plants, in cases formed of their excrement. Other species live on terrestrial plants, also in cases. The anus is situated on the upper surface, so that it is easy for the larva to cover itself with excrement. Pupation usually takes place in the ground.

The *Donaciinæ* occur chiefly in temperate regions. They are of moderate size, and not so brightly coloured as some of the other species, being usually bronzy green or brown. They live on aquatic plants. The larvæ are elongate, sub-cylindrical and whitish. They are remarkable in the fact of their living in the stems of aquatic plants, under water, obtaining their air supply from the plants by means of two spines at the

apex of the body. They pupate in cocoons attached to the roots.

II. *Cyclica*. This division contains the majority of the Chrysomelids, in which the thorax, with few exceptions, has distinct lateral margins and is usually broad. The head is more deeply set and the eyes are not prominent.

These beetles are from small to moderate size and very varied in shape. Many of them have brilliant warning colouring and many are bright red, blue or green, etc. They are typical leaf-eating beetles, and they and their larvæ are in many cases serious pests of crops : as, for example, the notorious Colorado Potato beetle and *Phædon brassicæ*, the Mustard beetle. The larvæ are usually very convex above, short and oval, with short legs, and are in many species brightly coloured. They live more or less openly on plants, and pupate sometimes on the plant and sometimes in the earth.

III. *Camptosomes*. The beetles in this division may be distinguished by the lines of the abdominal segments not going straight across the body, but curving, making the middle of the segments narrower than the sides. The pygidium is usually exposed. Many well-known sub-families are contained in this division. The species are small, cylindrical insects, brightly coloured, often in yellow and black. The long whitish larvæ live in small portable cases formed of their excrement. The larvæ of *Cryptocephalus*, for instance, are white, and have the abdomen doubled down and backward as far as the legs. The head and thorax only project from the case. The larvæ move jerkily, dragging the cases with them. The pupæ are attached to stems of grass and leaves. The larvæ of some of the *Clytrinæ* live in ants' nests, feeding on the vegetable refuse.

IV. *Trichostomes*. In this division the antennæ are not set very wide apart, and the elytra are more or less soft. The *Halticinæ* are small insects of oval form, and are often steel-blue in colour. The well-known "flea beetles" which have the power of jumping, and are very active, belong to this group. Their larvæ are more or less elongate, narrowing at each end. As a rule they mine in the stems and leaves of plants, and pupate in the boring. The adults eat holes in leaves.

The *Galerucini* include species whose larvæ live in the soil, feeding on the roots of plants, the adults eating the leaves.

V. *Cryptostomes.* The members of this division have the mouth small and more or less concealed.

The *Hispinæ* are somewhat flattened, with the thorax narrow and the antennæ set close together. The legs are short. There are often sharp spines on the thorax and elytra. They are variously coloured, some cryptically so. Eggs are laid in the tissues of plants, in which the larvæ mine. Pupation also takes place in the plant tissues. The larvæ are narrow at each end, and somewhat elongate.

The *Cassidinæ* are the "tortoise beetles." They are somewhat flat, rounded or oval in form, and have the pronotum extending over the head, concealing the mouth-parts, and the elytra often expanded at the sides. Some species have very brilliant colouring, which fades soon after death. Their larvæ are short and oval, of flattened form, with short legs. In many cases there are spines at the sides of the body. They shield themselves with dried excreta, carried on an anal process which can be turned over the back. They live on the leaves of plants and also pupate there.

All the *Chrysomelidæ* are vegetarians and all are diurnal.

In the *Genera Insectorum* various sub-families have been monographed: the *Clytrinæ* (Fasc. 49, 1906, 1907), *Criocerinæ* (Fasc. 23, 1904), *Donaciinæ* (Fasc. 21, 1904), and the *Sagrinæ* (Fasc. 14, 1903) by Jacoby and Clavareau; the *Hispinæ* by Weise in Fasc. 125 (1911), and the *Lamprosominæ*, Fasc. 159 (1914), *Chlamydinæ* and *Sphærocharinæ* by Achard. Several sub-families have been listed in the Berlin Catalogue, and others have been monographed in *Gen. Ins.* Fascs. 32 and 33 (1905) and Fasc. 159 (1914).

The 246 British species are described by Fowler.

The herbivorous habits of this large family cannot fail to make them of economic importance. Considerable damage is done to various crops by both larvæ and adults. Vines, potatoes, mustard, tobacco, beet, cucurbitaceous plants, maize and rice are some of the most important crops attacked. Species injurious to the vine are contained in the following genera: *Adoxus*, *Colaspis*, *Fidia*. Potatoes are attacked by *Epitrix*, *Galerucella*, *Leptinotarsa*, *Psylliodes*. The Crucifer

are attacked by *Haltica*, *Phædon*, *Phyllotreta*. Beet is attacked by *Cassida*, *Colaspis*, *Systena*, *Monaxia*. The *Cucurbitaceæ* are infested by *Aulacophora*, *Crioceris*, *Diabrotica*. Cereal-infesting species are: *Diabrotica*, *Hispa*, *Leptispa*, *Pachnephorus*. Various fruit trees are attacked by: *Diphucephala*, *Galerucella*, *Longitarsus*, *Melasoma*, *Monolepta*, *Crepidodera*. The pulses are attacked by: *Odontata*. Pests of fodder crops are: *Colaspidema*, *Haltica*. Sweet potato is attacked by *Chætocnema*, and the oil palm by *Cælænomenodera*. *Lochmæa* is destructive to the roots of heather.

Damage comes under several heads: first, leaf-eating beetles, which destroy foliage as adults; second, similar damage by larvæ; third, root damage by larvæ, usually associated with leaf destruction by adults; fourth, seedling destruction by adults as in the *Halticinæ*; fifth, damage by mining larvæ, which live as larvæ in the foliage: this occurs in *Halticinæ* and *Hispinæ*.

The control of many of these pests is often a matter of difficulty, and in some cases mechanical methods have to be resorted to, as with the flea beetles, which can be captured in large numbers by dragging through the fields of crops a sort of wooden trap with sloping sides covered with a sticky material, on to which the agitated beetles jump and are held fast.

Cerambycidæ.

Longicorns.

Head obliquely inclined or sub-vertical. Antennæ long, their bases partly encircled by the eyes. Upper surface pubescent. Last joint of palpi not pointed at apex. Anterior tibiæ not grooved beneath.

This family contains a great number of species, many of them large, fine insects. It was originally included with the following family, the *Lamiidæ*, but on account of various external characters it was considered advisable to separate the two groups. The chief and most easily recognizable difference between the two families is in the position of the head, the front of which, in the *Cerambycidæ*, is subvertical or inclined forward,

and in the *Lamiidæ* is vertical or even inclined inward. Other differences are: the apex of the last joint of the palpi being pointed in *Lamiidæ*, but not so in this family, and the underside of the anterior tibiæ not being grooved beneath in this family, but grooved in the *Lamiidæ*.

A great many of the Cerambycids are well known and do not need much description; their elongate form, parallel sides and long or very long antennæ, are features which cannot fail to be noticed by the most casual observer. In a few species

FIG. 50.—*Lamia textor*. (× 2.)

the antennæ are of more medium length and the body is more rounded and less elongate.

The colouring is very variable and there are admirable examples of cryptic coloration, many species toning perfectly with the moss or lichen-covered branches on which they rest. Others are brightly coloured, some being very beautiful. They range in size from less than half an inch to fine big specimens, two, three or more inches in length. The integument, with few exceptions, is hard.

The head is large, with strong, prominent mandibles and, as a rule, large eyes. The antennæ are generally very long and have their bases partly encircled by the eyes. They vary in form, sometimes being dentate and sometimes clothed with tufts of hair. The prothorax is stoutly built. The elytra closely fit the abdomen, but in some cases do not entirely cover it. The wings are large and functional. The legs are long and often clothed with tufts of hair; the tarsi are pubescent and have the third joint bilobed. There is not much difference between the sexes, the males possessing larger mandibles and, as a rule, longer antennæ. Many species stridulate by rubbing the posterior edge of the prothorax on a grooved surface on the mesothorax, and others by rubbing the hind femora against the edge of the elytra. Several emit an odour, sometimes pleasant and sometimes disagreeable. The British *Aromia moschata*, known as the "musk beetle," is a typical instance.

The adults are all herbivorous, feeding principally on the foliage of trees. They are both diurnal and nocturnal of habit, and in some species often take to flight.

The life-histories are very similar, both in this family and the *Lamiidæ*. The larvæ are all wood-feeders, living in the trunks and branches of trees and under bark. Eggs are laid on the bark or in cracks, and the larvæ tunnel into the hard wood or burrow along under the bark. The larvæ are elongate, white or yellowish grubs, with a small horny head and strong mandibles, well adapted for gnawing wood. The thorax is slightly swollen, in a few cases considerably so, causing the larvæ to resemble those of the *Buprestidæ*. Legs are absent, their place being taken in some species by swellings on the body surface, which assist the larvæ in their progress along the tunnels. Some species have dorsal plates on the thoracic and abdominal segments. Pupation takes place in the tunnels, the larva sometimes making a small chamber by closing up the tunnel at each end of its body, and sometimes forming a cocoon of chips and anal secretion. The length of the life-history is usually long, in many cases extending over three years. During their lives the larvæ bore long and tortuous tunnels through the wood, often doing great damage to valuable timber.

Lamiidæ.

Except in the characters already mentioned, this family does not differ in structure, life-histories or habits from the *Cerambycidæ*. The same wide range of colouring is seen, the examples of cryptic resemblance and protective mimicry being, if anything, more highly emphasized. Many beetles in this family resemble wasps, bees and other harmful insects, including other protected beetles. Their movements also are like those of the insect they wish to mimic: for instance, the British *Clytus arietis*, with its yellow and black markings, runs rapidly about leaves and stems of bushes in the same manner as a wasp.

The larvæ, their habits, and the adult habits, are all similar to those of the *Cerambycidæ*.

These families together number, as far as is known, about 13,000 species, which are very widely distributed.

The *Cerambycinæ* and the *Lamiinæ* have been listed in the Berlin Catalogue by Aurivillius. Lameere lists the *Prioninæ* as a separate family in that catalogue. Lameere has monographed the *Prioninæ* in *Genera Insectorum*, Fasc. 172 (1919), and Boppe the *Cexambycidæ* (*Disteriinæ* to *Septurinæ*) in Fasc. 178 (1921).

The British species of the two families number fifty-three, and are dealt with by Fowler.

In the forest regions of tropical and temperate countries, these beetles do a great amount of damage, much timber being lessened in value and often rendered totally unfit for commerce. Trees are often killed by the borings of these insects.

As well as forest and shade trees, many fruit trees and bushes are also attacked: orange, coffee, mango, cocoa, lime, apple, pear, etc., all supplying breeding places for the larvæ. The adults are in some instances injurious to foliage.

The citrus trees are attacked by species belonging to the following genera: *Acrocinus*, *Diploschema*, *Elaphidion*, *Leptostylus*, *Stromatium* and *Uracanthus*. Coffee is infested by *Anthores*, *Monohammus*, *Moecha* and *Xylotrechus*. *Batocera* infests the mango. Cacao is injured by: *Eudesmus*, *Glenea* and *Steirastoma*. Apple is attacked by: *Elaphidion*, *Leptostylus* and *Saperda*. Vine, fig, raspberry, gooseberry and

mulberry are more or less attacked by: *Oberea*, *Prionus*, *Phryneta*, *Xylocrius* and *Clytus*. *Agapanthia* is injurious to *sunflower*, and *Ataxia* to cotton. Rubber is attacked by *Coptops*, *Epepeotes*, *Inesida*, and *Tæniotes*.

(*f*) RHYNCHOPHORA

Head produced into a rostrum, variable. Antennæ usually clubbed and elbowed. Tarsi five-jointed, apparently four-jointed, first three joints pubescent.

Six families are contained in this sub-order. Two of them are of great economic importance.

Brenthidæ.

Head and prothorax elongate. Antennæ straight, nine- to eleven-jointed. Rostrum horizontal, either long or short, with stout mandibles. Elytra cover pygidium.

About 1,900 species are contained in this family. They are widely distributed in tropical regions, but very few are found in temperate regions.

They are allied to the *Curculionidæ*, but are more elongate and narrow in form. In colour they are usually dull red-brown or yellowish, and are bare and shining. They have been divided into two sub-families: the *Brenthinæ* and the *Ulocerinæ*. In the *Brenthinæ* sexual dimorphism is strongly apparent, the males having a broad, short rostrum, while in the females the rostrum is slender and often longer than the body. The mandibles are well developed. The head is constricted behind, and the antennæ are eleven-jointed. The legs are long and stout, with the fore femora and tibiæ often expanded and toothed. The elytra completely cover the abdomen. The *Ulocerinæ* in nearly all cases have nine-jointed antennæ, and show much less, if any, structural difference between the sexes.

The family as a whole are wood-borers and live in decaying wood, on which the majority of them feed. One or two genera are considered to be predaceous on other larvæ. Little is

known of the earlier stages; the larvæ are said to be furnished with short legs, an unusual character in the *Rhynchophora*.

The family has been monographed by Schönfeldt in *Genera Insectorum*, Fasc. 65 (1908). Jacobson has written on this family. The species have been listed by Schönfeldt in the Berlin Catalogue. There are no British species.

Platyrrhinidæ (*Anthribidæ*).

Rostrum short, blunt and flat. Antennæ straight, often long. Pygidium exposed; propygidium deeply grooved in the middle.

This family contains about 1,000 species, chiefly confined to the tropics, very few being found in the temperate regions.

They vary from small to moderate-sized insects, variable in general appearance, some resembling the *Lamiidæ*, and others certain of the *Curculionidæ*. They are pubescent, not brightly coloured, but often have markings of black, grey, brown, or white.

The antennæ are straight, sometimes with a three-jointed club, and in the males of some species, very long. The rostrum is very short and broad; the mandibles are flat and curved, pointed in some species and emarginate at apex in others. The elytra leave the pygidium exposed: the propygidium is deeply grooved in the middle. The legs are of moderate length, with four-jointed tarsi, the third joint often being very small and concealed by the second joint. These beetles are not as a rule active, but a few have the power of leaping. They occur in dead wood, fungi, and sometimes on tree trunks and old hedges.

The larvæ are soft, white grubs, some with legs, others without, or with three pairs of pseudopods. These larvæ live in dead wood and have also been found in large seeds and nuts. One species, *Arœcerus fasciculatus*, has been known to breed freely in coffee beans. The larvæ of *Brachytarsus* are said to feed on *Coccidæ* and are probably the only case of carnivorous *Rhynchophora*.

Bovie has listed the species, 1905. The eight British species are described by Fowler.

Curculionidæ.

Weevils.

Labrum absent. Antennæ clubbed and elbowed. Rostrum variable, usually distinct.

This is a huge family containing some 30,000 species of so variable and complex a nature that up to the present their classification seems a somewhat hopeless task, and their division into numerous sub-families, legions, cohorts, tribes, etc., tends rather to heighten the complexity than lessen it. Their distribution is extremely wide, they being found in all parts of both temperate and tropical regions.

In general appearance they are easily recognizable by

Fig. 51.—*Hylobius abietis* (*Curculionidæ*). (× 3½.)

reason of the distinctly prolonged rostrum and geniculate antennæ borne by nearly all of them. They range in size from those an eighth of an inch in length to some about two inches. There are a considerable number of medium-sized species with a length of from a quarter to half an inch. Their colouring is generally dull: brown, grey or buff, more or less blotched and marked. Some, however, are of brighter appearance, being rich reddish-brown, light green or blue. Cryptic colouring is very noticeable in this family. In the majority of cases the body is clothed with scales, and it is these scales that usually make up the colour scheme, the actual integument being quite darkly coloured, if not black. Some species are clothed with a delicate, mealy covering, similar to an alkaline solution secreted by the insects, and leaving, after evaporation, a sort of efflorescence.

The head varies in size and is produced in front into a more

or less distinct rostrum, in some cases short, blunt and thick-set; in others long, slender and curved, or almost straight. The somewhat small mouth-parts are situated at the apex of the rostrum, the mandibles moving horizontally in all cases, with the exception of the genus *Balaninus*, in which they are vertically placed. With the exception of a few genera, the palpi of all are exceedingly small and rigid. The eyes are small and situated at the base of the rostrum. The antennæ project from the sides of the rostrum, in some species near the apex, in others not far from the base. They are all more or less geniculate and consist of an elongate basal segment or scape and six or seven short segments terminated by a three- or four-jointed club. The prothorax is well developed and closely articulated; the abdomen, which is large and thick-set, is completely covered by the neatly fitting elytra. The wings are ample and much used by a number of species. The legs are of moderate length and often have the apex of the femur swollen. The tarsi are apparently four-jointed, the basal three rather flattened, and the third, as a rule, bilobed; the fourth joint is elongate. The males are often smaller than the females, and in a number of cases may be distinguished by some character of the fore-legs.

The life-histories of a considerable number of species have been worked out, and it has been found that the eggs are of two types: those laid on the outside of a plant, and those laid in the plant tissues. The exposed eggs are usually small, oval, smooth and hard, while the concealed ones are more elongate and soft. A considerable number are laid, scattered about over several plants. The resulting larvæ are soft, white, legless grubs, with a fleshy body, slightly curved and thickened posteriorly; the head is exserted and is usually brown in colour. These larvæ live in and on all parts of the plants, feeding on the tissues; roots, leaves, stems, flowers, buds, twigs and fruit are all attacked by some species or another. Pupation takes place in the majority of cases in the plant, some species forming cocoons of fibrous material, others just enclosing a small chamber in the plant tissue. Some of the root-infesting larvæ pupate outside the root in cocoons made of earth, while many which feed externally form cases of excrement or a gummy secretion from the anus.

The duration of each stage varies according to species and climatic conditions. While some only complete one life cycle in a year, others are many-brooded and continue breeding as long as suitable larval food is available. Hibernation most commonly takes place in the larval and adult stages, the latter stage particularly, in the case of one-brooded species. The adults are very active and may be found on all kinds of herbage and trees. Some only feed at night, while others are diurnal of habit. It is thought that one species may possibly be predaceous; but all the rest are undoubtedly herbivorous. There are aquatic species, the adult swimming in fresh water. Many species very successfully " sham dead " on the approach of danger, drawing the legs and antennæ close up to the body and falling off the plant into the surrounding herbage, which renders it difficult for them to be found.

The larvæ of a number of these beetles are chosen as hosts by many parasitic insects, and the adults are eaten by birds and predaceous insects.

Although some work has already been completed on this family both with regard to classification and bionomics, much still remains to be done. Some of the sub-families have been monographed in *Genera Insectorum* by Bovie, Lea, and Wagner, in Fascs. 70 (1908), 71 (1908), 89 (1909), 98 (1909), 130 (1912). Wagner also lists the species of the *Apioninæ* in the Berlin Catalogue. Fowler gives descriptions of the 460 British species.

Economically, this family can be ranked among those of the greatest importance. When one considers the vast numbers of species and the herbivorous habits of all, it is easy to realize how serious a menace to agriculture the family as a whole can be. It is chiefly in the larval stage that the greatest damage is done; but some adults are also very destructive. As already mentioned, no part of a plant is free from attack, and, feeding concealed in the tissues as many of the larvæ do, it is difficult to eradicate them. The foliage of trees is eaten by several species, particularly those of the genera *Attelabus* and *Rhynchites*, the adults preparing a case for the protection of the egg and larva, by cutting nearly across a leaf and rolling it up into a neat tube or funnel in which the grub feeds. Whole trees, particularly oak and birch in this country, may often

be seen treated in this way. Various coniferous trees are injured by the ravages of some species. Many fruit trees are injured in some manner by either larvæ or adults. *Anthonomus pomorum* does a great deal of damage to apple trees in America and Europe.

Anthonomus grandis, the notorious "Cotton Boll Weevil," does harm to the fruiting bolls of the cotton plants, causing great loss of crop. There are also weevils of other genera which attack cotton.

Species of the genus *Apion* are serious pests of many leguminous fodder crops.

Stored grain is attacked by the genus *Calandra*, eggs being laid in individual grains, of which the inside is eaten by the resulting larva.

There are many other genera containing species of economic importance to various crops, etc.: Cotton, as well as being attacked by the notorious *Anthonomus*, is also infested by *Alcides*, *Chalcodermus* and *Pempheres*. The fodder crops are infested by *Apion*, *Hypera*, *Phytonomus* and *Sitones*; fruit trees by *Balaninus*, *Cœliodes*, *Conotrachelus*, *Cryptorhynchus*, *Leptops*, *Magdalis*, *Orchestes*, *Otiorhynchus*, *Pachnæus*, *Peritelus*, *Craponius*, *Phyletinus*, *Phyllobius*, *Rhynchites*, *Rhynchophorus*. Cereals are attacked by *Sphenophorus*, *Exophthalmus*, and *Lissorhoptrus*. Crucifers are injured by *Barynotus*, *Ceutorhynchus*, and beet, potato, etc., by *Cleonus*, *Desiantha*, *Cylas*, *Tanymecus* and *Trichobaris*. *Lixus* is injurious to rhubarb, and *Balanogastris* to kola-nut.

Scolytidæ (*Ipidæ*, *Platypidæ*).

Bark-borers.

Rostrum short or absent. Antennæ short, elbowed and clubbed. Anterior coxæ contiguous. Tarsi variable, last joint long.

About 1,500 species are contained in this family: they are widely distributed throughout the world, particularly the great forest areas.

They are all small, cylindrical insects, differing from the

Curculionidæ inasmuch as the rostrum is very short or often practically absent. Their colouring, as is usual with most wood-boring beetles, is dull black or brown. The head in some species is prominent; but in others it is partially covered by the hood-like formation of the thorax. The antennæ, which are inserted on the sides of the head, are elbowed and strongly clubbed. The rostrum, if present at all, is short and broad. The mandibles are short, curved, and more or less toothed on their inner side. The thorax is well developed, seldom narrower than the elytra, and often much sculptured. The elytra cover the abdomen. The legs are compressed, moderately stout, with the anterior tibiæ invariably denticulate or crenulate on the outer edge, and the last tarsal joint long and furnished with simple claws. The anterior coxæ are contiguous.

The larvæ resemble very closely those of the other families of the *Rhynchophora*, with the difference of a slightly longer head and more strongly developed mandibles. They are all much alike, with the exception of that of *Platypus*, which is more elongate and terminates in a short spine.

The mode of oviposition differs from that of the other *Rhynchophora*, in the fact of the female entering the wood or plant tissue to lay the eggs, whereas the rest of the *Rhynchophorous* families lay the egg from the outside of their chosen food.

The majority of species in this family are borers in wood and bark, on which some of them feed. Some of them live on the fruiting bodies of certain fungi which grow in the borings and are said to be cultivated by these beetles. A few, belonging to the genus *Thamnurgus*, live in the stems of plants such as *Euphorbia*, *Delphinium*, etc.

The habits of these beetles are of great interest and well worthy of notice. Some species are monogamous, others polygamous. In the former case the female prepares the first bore, and after mating, makes numerous tunnels at right angles to her first bore, laying an egg in each. The male never enters the nursery tunnels. In the latter species it is the male who makes the main boring, from which his numerous wives make other bores, and tunnels out of those again, in which the eggs are laid. These latter tunnels often leave the

bark and extend right into the wood. The species of *Trypodendron* have this habit. In some species the system of tunnelling is very complex.

There is a monograph on the family by Hagedorn in *Genera Insectorum*, Fasc. 111 (1910). A list of the species will be found in the Berlin Catalogue.

The fifty-three British species are dealt with by Fowler.

This family is one of great economic importance owing to the timber-infesting habits of its members. Not only old and weakened trees are damaged, but vigorous and healthy trees are also attacked. Fruit trees also come within range of their destructive powers : *Xyleborous dispar*, the "Shothole borer," being a familiar instance. The other chief pests are contained in the following genera : *Cryphalus* and *Platypus* attack apple. *Hylastes* breed in stems of clover. *Scolytus* and *Phlœotribus* attack plum and peach. *Hylesinus* and *Hypoborus* attack olive and fig. *Stephanoderes* and *Xyleberus* are injurious to coffee bushes.

Aglycyderidæ.

Head short, very broad, triangular, broader than apex of prothorax. No rostrum. Antennæ long, eleven-jointed. Legs short and stout. Tarsi three-jointed.

Both this family and the next are very doubtfully Rhynchophorous, and seem to have been placed there for want of a better or more correct position.

There are only a few species in this family, and they occur in New Zealand, New Caledonia, and the Canary Islands.

The head is very broad, short and triangular and is not produced into a rostrum ; it is broader at the base than the prothorax, which is very round. The antennæ are long and somewhat moniliform. The legs are short and stout, with three-jointed tarsi.

There is uncertainty as to the habits and life-history of these beetles ; but one species is believed to live in the stems of *Euphorbia*.

Proterhinidæ.

Elongate, oval. Head sub-triangular. Eyes very prominent. Antennæ long, slender. Legs stout; tarsi three-jointed, second joint lobed.

This family is made up of one genus containing about 120 species confined to the Hawaiian Islands.

As far as general structure goes, they certainly have more right than the preceding family to be placed in the *Rhynchophora*, as the females in particular have quite a distinct rostrum. They are small and somewhat elongate, plumose, and marked on the elytra. The head is of moderate size and sub-triangular: bearing very prominent eyes and long slender antennæ, which have the apical joints slightly thickened. The males have the head only very slightly, if at all, produced. The sides of the pronotum are rounded. The legs are stout, particularly those of the female, with three-jointed tarsi, the second joint broad and lobed, and the terminal joint long. The early stages of these beetles are not as yet known. The adults live in dead wood in forests.

There is a list of the species in the Berlin Catalogue.

Sub-Order III. *LAMELLICORNIA*

Tarsi five-jointed. Apical joints of antennæ expanded on one side to form a closed or open club.

Four families are contained in this sub-order, one of them being of economic importance.

Passalidæ.

Flattened. Antennæ pectinate, not elbowed. Labrum large, mobile. Pygidium covered by elytra.

This family, which contains about 500 species, is confined almost entirely to the tropical regions of both the Old and New Worlds. One species only occurs in the more northerly portion of North America.

They are of moderate to large size, and show very little

variation in general appearance, all having a characteristic elongate-oblong shape, depressed form and uniform black or brown colouring, more or less shiny. The elytra are marked with a number, usually ten, of deep, longitudinal lines. The head is large and in many species has a rugged appearance above. The antennæ, when not in use, are folded back under the head. The prothorax is broad and loosely applied to the mesothorax; the elytra cover the abdomen completely. The legs are strong, with the fore tibiæ broadened and toothed, well fitted for digging: the posterior legs are more slender and have the tibiæ hairy. The under side of the body is clothed with hair. There is no external structural difference between the sexes, the mandibles of the male not being enlarged as in the *Lucanidæ*.

The larvæ are worthy of note, both on account of their structure and habits. They have the head smaller and are more slender than the Lucanid larvæ. The fore and middle pair of legs are moderately long, but the hind pair are short and of peculiar formation, having a very small coxa, and a trochanter about six times its length. In a few cases there are claws. The trochanter is modified to form a scratching instrument on a stridulating area on the coxæ of the middle pair of legs; both larvæ and adults stridulate very often.

The family life of these beetles, as observed by Ohaus, is very interesting. The parent beetles live with the young larvæ in tunnels in rotting stumps, the adults biting off the wood and chewing it into a soft condition for their young, whose jaws do not seem to be strong enough to enable them to gnaw it for themselves. It is probable that a digestive secretion is mixed with the food by the adults. Even when the young Passalids have reached maturity, their parents for a time continue to feed them. The power of stridulating possessed by both larvæ and adults is possibly of use in guiding the larvæ back to their parents, should they by some mischance become separated. This possibility is heightened by the fact of the larvæ having no trace of eyes. Gravely (1914–1918) is the most recent authority.

Lucanidæ.

Labrum small and fixed. Antennæ elbowed, with a fixed, pectinate club. Mandibles strongly developed in the male. Pygidium covered by the elytra.

This family of large, fine-looking insects contains some 750 species fairly widely distributed, but chiefly in tropical countries, a great number of them being found in the Indian and Indo-Malayan region.

They are from moderate to large size, many of them attaining a length of four inches and over. Their shape is oblong and somewhat flattened. The colouring is generally a uniform black or brown, but some species wear a very striking uniform of black and sharply contrasting bright brown. They are not as a rule very shiny. The greatly enlarged mandibles of the males cause them to be very easily recognized. The head is large, with moderately long antennæ, which are elbowed and bear a four-jointed, pectinate club. The eyes of many species are divided by a ridge, the larger portion being below. The size of the head and mandibles vary greatly, some males being found with mandibles scarcely larger than those of the female. The head of the larger species is broader than the thorax, and in some cases as broad as the elytra. In the female the head is usually much narrower than the thorax, and bears short but stout mandibles, stronger and of greater use than those of the male. The elytra completely cover the abdomen. The legs are moderately long; the anterior pair are often toothed on the tibia.

The larvæ are large, white, fat grubs; that of *Lucanus cervus*, a British species, may be taken as a typical example. It is white and almost cylindrical, with a conspicious brown head, short antennæ and strong mandibles. The legs are moderately long. The apical portion of the body is curved and the last segment is slightly smaller than the preceding. Pupation takes place in a cocoon formed of chips and wood dust. The larval period, which lasts for three or more years, is spent in decaying tree trunks, the insect feeding entirely on the wood and occasionally attacking the roots. The adults are also vegetable feeders, and may sometimes be found eating

the exuding sap of trees. The males may often be seen on the wing during warm summer evenings.

A list of the species by G. Van Roon is to be found in the Berlin Catalogue.

There are only two British species, one being the commo and well-known "stag-beetle," and the other equally commo but less generally known.

Sinodendridæ.

Completely cylindrical. Antennæ short and stout, wit pectinate club. Mandibles short in both sexes. Anterio part of thorax nearly vertical. Legs short, robust; femor hardly visible beyond elytra. All coxæ contiguous.

The few species making up this family are confined to Euro and North America. Until recently they were included wit the *Lucanidæ*, but are so different in structure that it ha seemed reasonable to form a separate family of them.

They are all of moderate size, completely cylindrical, black not very shiny, but usually thickly punctured. The antenna are short and fairly thick, with a pectinate club, but ar not elbowed. The mandibles are not enlarged in eithe sex, and are, in fact, very short and concealed by the hea The anterior portion of the thorax is of curious formation being cut off very sharply at an angle of 80°; the angle is no so well defined in the female. On the front of the head th male bears a fairly long, stout horn, which in the female i only represented by a small tubercle. The elytra are strongl punctured and completely cover the abdomen. The legs ar short and stout, with the femora scarcely, if at all, visibl beyond the elytra: a character which is useful for recognition All the coxæ are contiguous.

The larvæ are more slender than those of the *Lucanidæ* narrowing toward the anal extremity, which does not curve under as is characteristic of the Lucanids. The head is some what small. All stages may be found in rotting stumps and decaying trees, particularly ash and willow. They are seldom known to attack vigorous and healthy trees. There is one British species, mentioned by Fowler.

Scarabæidæ.

Dung beetles and Chafers.

Convex. Size very variable. Lamellæ of antennæ, movable, co-adaptable. Antennæ seven- to eleven-jointed, variable, first elongate. Pygidium usually exposed. Six visible sternites. Legs usually fossorial.

This is a very large family. Its members are very widely distributed through, chiefly, tropical regions. It is divided into two main sub-families; the *Scarabæinæ* and the *Melolonthinæ*. The *Melolonthinæ* have been classed by some authors as a separate family. The *Scarabæinæ* are small to large insects, sombrely coloured as a rule, but in some tropical species, metallically coloured. They are convex, oblong and thick-set. The head is large and projects forward, plate-wise, concealing the mouth-parts. The mandibles are short and stout. There is often a horn or spine-like process on the head. The antennæ are seven- to eleven-jointed, with the first joint long and the lamellæ of the club movable. The prothorax is large and often bears horny projections. The elytra are hard, somewhat rough, and leave the pygidium exposed. The legs are long and stout, well adapted for digging, with the tibiæ broadened and spined. The tarsi are slender, and absent in the anterior legs of some large species. There are six visible ventral segments. The abdominal spiracles are all covered by the elytra.

Fig. 52.—*Geotrupes stercorarius* (*Scarabæidæ*) (× ¾.)

Both larvæ and adults, with few exceptions, live in or near, and feed on, dung. Some feed on dead animal matter. Some species collect dung, form it into balls, roll them along the ground

and take them down into the ground, where they form the food supply of the larvæ. The flat-shaped head is of great service in digging, moulding and rolling the dung. Other species live in burrows under dung masses, packing the burrows with the dung they have carried down. Eggs are laid in these stores, on which the larvæ feed. The adults also feed on dung. They have large wings, and in many cases may be seen in flight. Pupation takes place in the burrow. Fabre gives an excellent account of these beetles.

The *Melolonthinæ* may be distinguished from the *Scarabæinæ* by having one or three abdominal spiracles visible below the elytra.

They are moderate to large-sized insects, thick-set and oblong in form, with the head smaller than in the *Scarabæinæ* and not produced. The thorax is large and rounded; both head and thorax of some species, especially the males, have long or short horny processes. The anterior legs are often broadened, and well adapted for digging in the soil. There are spines on the posterior legs. The wings are large and often used. Many stridulate by rubbing one portion of the body against another, a habit also possessed by many of the *Scarabæinæ*. Many species are brightly coloured, several brilliantly so; others are more sombre in brown or buff.

The larvæ, which in many cases resemble those of the *Scarabæinæ*, are soft, white grubs, with curved bodies and apical segment somewhat swollen. The legs are of varying length.

The *Melolonthini* proper are the Cockchafers, which are usually dull-coloured insects. They are nocturnal, often flying at night and feeding on leaves and flowers. The dingy-white larvæ live in the soil, feeding on plant roots. They pupate in cells in the soil.

The *Rutelini* are chiefly tropical species, often brilliantly coloured. The larvæ feed on roots and the adults on the foliage of various plants.

The *Dynastini* are nearly all large species, some of them being the giants of the beetle world. The males of several species have curious, long or short horns or processes on the head and prothorax. They are not as a rule brightly coloured. Their larvæ live in old trees, in rotting vegetable matter and in

plant roots. The pupa is enclosed in a hard case. The adults live on plant tissues.

The *Cetoniini* are moderate-sized insects, and many of them have very beautiful colouring. They are somewhat flat in form. The males of some species have protuberances on the head and thorax. They are diurnal and often found on flowers. The larvæ live in decaying vegetable matter and in roots.

Many sub-families of the *Scarabæidæ* have been monographed by Schmidte in *Genera Insectorum*, Fasc. 150 (1913), and also listed by him in the Berlin Catalogue. Dalla Torre lists the *Melolonthini*, Gillet the *Coprini*, and Schenkling the *Cetoniini* in the Berlin Catalogue. *Gen Ins.* Fasc. 110 (1910) and 7 (1902), also deal with this group. The eighty-two British species are listed by Fowler.

The habits of the *Scarabæinæ* render them of good service to the agriculturist, as they carry down into the earth manure which might otherwise be washed away, dried up, or in some manner wasted.

The other sub-families are in many cases injurious: their larvæ damaging the roots of various plants and trees, the adults attacking flowers and foliage. Wheat, rice, maize, sugar-cane, etc., are often attacked. The adults of some species eat the foliage of vine and oil-seed crops. Coco-nut palms are attacked by species of *Oryctes*: the beetles eating down into the growing point of the palm, often causing it to die. The genera containing the more important economic species are: *Apogonia*, *Heteronychus*, *Ligyrus*, *Phytalus*, *Rhapæa* and *Xylotrupes* as pests of cane. Coco-nut is attacked by *Adoretus*, *Apogonia*, *Oryctes*. The vine is attacked by species of *Anomala* and *Macrodactylus*, which latter also attacks apple; other apple pests are *Anoplognathus* and *Melolontha*. Orange is infested by *Cetonia* and *Phyllognathus*. *Phyllopertha* attacks crucifers, and *Lachnosterna* wheat and grass crops.

The eradication of these pests is in many cases difficult, and mechanical devices, such as the placing of various traps, are often the only methods which give any results.

STREPSIPTERA

STYLOPIDÆ.

Minute insects, parasitic in the interior of Hemipterous and Hymenopterous insects. Prothorax very small. Elytra reduced to small slips. Metathorax large. Males with large wings, no cross-veins. Tarsi variable, without claws. Females blind and larviform, never leaving host.

The insects contained in this order and family are of most abnormal character. It has been thought that they come nearest in structure to the *Coleoptera*, and were at one time placed in that order; but on account of their extraordinary characters it has been considered best to keep them separate.

FIG. 53.—Female of *Dascyrtocara undata* (lateral view) from *Onometropia undata*.

(After Pierce—much enlarged.)

Four genera are known, and the species are probably more numerous than it is thought, as their small size and peculiar habits do not tend to make them very noticeable. They have been recorded from North America, Brazil, Mauritius, and Tasmania. All the four genera are present in Europe. They are very small and are parasitic in the bodies of various Hymenopterous and Hemipterous insects.

The males are winged, with a very small head, and sucking mouth-parts. The antennæ are five- or six-jointed, sometimes branched or flabellate. The prothorax is very narrow, being reduced to a mere band, while the metathorax is unusually large. Elytra are present in the form of small, more or less twisted, slips. The wings are large, with radiating veins, but no cross-veins, and are folded longitudinally when at rest. The legs are of moderate length, with tarsi of two, three or four joints, and without claws. They are usually black.

The females are very small and never become other than larviform, being like a small legless maggot, with one end

restricted to form a sort of head. They never leave the bodies of their hosts.

The larvæ, in the first stage, are triungulins, and emerge from the body of the female, in which the eggs are hatched. The triungulin larva, which is very active, reaches by some means or other the larva of the host insect and bores into the fat-body, on which it feeds, subsequently moulting and becoming a soft, legless maggot, after which it feeds till full-grown and then pupates, still in the fat-body. If a male, it emerges from the body and flies away; but if a female, the larval

Fig. 54.—Male of *Xenos* from *Polistes hebræus*. (× 12.)
(After Lefroy.)

shape is more or less retained and it remains in the body, with only the supposed head portion extruded, by which the males effect fertilization.

In some forms the ovaries open on the dorsal surface of the body, attainable for fertilization by the male.

The insects are not killed by the parasites, but usually complete their metamorphosis, and the Stylopid and its host often arrive at the adult stage together, when the protruding portion of the Stylopid may be visible between two of the abdominal segments.

The adult males are short-lived and do not appear to take

much nourishment. Some species belonging to the genus *Xenos* only live for about twenty minutes, while others, of the genus *Stylops* may exist for a day or so.

The species of *Xenos* are very active, and fly with great rapidity among the wasps, in the colonies of which they breed. The males are known to fly both by day and by night, occasionally coming to light.

The insects parasitized are : bees of various genera, certain wasps, and a few Homopterous insects.

The genus *Stylops* parasitizes bees of the genus *Andrena*. *Elenchus* attach themselves to bees like *Bombus*, and *Halictophagi* to the *Halictus*. *Xenos* chiefly pay their attentions to wasps of the genus *Polistes*, and occasionally to *Sphex*.

As a rule, only one Stylopid is developed in the body of the host ; but cases are known of bees in which three or four have been found ; while some of the Polistes have been observed to have as many as ten Xenos in them. Pierce is the chief authority on this family. *Proc. U.S. Nat. Mus.* 54, pp. 391–507 (1918), and *Gen. Ins.* Fasc. 121 (1911).

Three of the genera occur in Britain, with one species each. They have been described by Fowler.

THYSANOPTERA (*Physapoda*)

Thrips, Blasenfüsse, Vesitarses, Fringe-wings.

Small, elongate insects with two pairs of narrow wings fringed with long hairs ; mouth-parts piercing and sucking.

Thrips are widely distributed, being found in both temperate and tropical lands. They are recognizable in the field by their small size, the nature of their wings and their rather peculiar, jerky walk. The nymph is white or yellow, sometimes orange, and the adult is brown or black. Colour is of little significance, though the adult is often difficult to distinguish, with its dark body and light wings, on the whitish areas of "thripped" leaves dotted with the black spots of excreta which the insect deposits.

The head is large, and flat on top ; in profile it is triangular, the forehead forming the apex. The mouth-parts are drawn right back to lie almost between the fore coxæ, the cavity of the mouth thus pointing straight downwards. The eyes are large and contain relatively few facets. Two or three ocelli are always present in winged and absent in entirely wingless forms. The general arrangement of the mouth-parts resembles that of a Hemipteron ; they are fitted entirely for sucking. The region constituting the mouth is in the shape of a cone, formed by the clypeus, labrum, labium, and maxillary sclerites. Inside this cone work the piercing mouth-parts, which are asymmetrical, consisting of one mandible and two maxillæ. The left mandible is fairly short and stout ; the right is a mere rudiment. The maxillæ consist of three parts : the piercing "stylet," generally longer and more slender than the mandible, the external maxillary sclerite, bearing a two or three-jointed palp, and a short piece connecting the other two. The labium also bears a pair of short, two- or four-jointed palps (Peterson, 1915).

Turning next to the thoracic region, the prothorax is distinctly separated from the mesothorax, while the meso- and meta-thorax are closely united. The legs are very uniform

in the various groups, although the fore-legs are often shorter and thicker and more specialized than the others. All the tarsi are reduced, being generally two-, but sometimes one-jointed; the last segment bears a bladder-like organ, capable of being extruded or withdrawn at pleasure. The wings of Thrips are quite unique in their combination of peculiar characters. They are long, narrow, and membranous, with few veins; the anterior margin is generally, and the posterior margin always, fringed with long, delicate hairs. When at rest, the wings lie horizontally along the abdomen. They are sometimes reduced to mere pads, and in a few species are entirely absent. Three pairs of spiracles are always present, a fourth occurs in all *Tubulifera* and many *Terebrantia*; in a few species eleven are present. In the adult, one pair is situated on the mesothorax and first and eighth abdominal segments. The fourth pair, when present, is very small and is found on the metathorax; while in those species with eleven pairs they are situated on the meso- and meta-thorax and the first to the ninth abdominal segments. In the "larval" stages, i.e. first and second instars, the arrangement of the spiracles is the same, except that the first pair occurs on the second abdominal segment instead of on the first. The abdomen consists of ten segments, of which the last is conical or tubular in form. Distinction of the sexes, in those forms where the female has no ovipositor, is often a matter of some difficulty. In the *Terebrantia*, the female has an external ovipositor, which is saw-like and composed of four valves, and is situated ventrally on the eighth and ninth segments of the

FIG. 55.—Adult of *Tæniothrips pyri*. (× about 60.)
(After Moulton—slightly simplified.)

abdomen. The genital opening is between the eighth and ninth segments. The end of the abdomen is generally conical in form. Usually the male is much smaller than the female; a protrusible penis lies withdrawn inside the ninth abdominal segment, and the genital opening is situated between the ninth and tenth segments. The abdomen is usually blunt at the end. In some forms the ninth segment bears processes which probably assist in copulation. The male, too, is often lighter in colour and more active than the female. In the *Tubulifera*, the end of the abdomen is tubular in form and the genital pore is situated between the ninth and tenth segments in both sexes. The female has no ovipositor, to act as a distinguishing feature; but lying ventrally on the ninth abdominal segment, near the posterior edge, is a short, chitinized rod, which, however, is not easily visible in dark-coloured forms. The male is generally smaller and narrower. The base of the tube at the end of abdomen is emarginate on the ventral side, and a semicircular opening is present there, through which the penis can be extruded. In many species the male has thicker femora in the fore-legs and stouter spines on the fore-tarsi, while in some species the females are winged, the males are wingless.

Very little appears to be known of the internal anatomy of the *Thysanoptera*. There are two kinds of salivary glands, situated in the thorax and abdomen. The ducts from these unite and pass into a Y-shaped structure, which leads into the cavity of the mouth behind the pharynx. The pharynx forms a distinct sucking apparatus; it leads into a straight, simple alimentary canal. Four Malpighian tubules are present. In the female, the ovary is simple, with six to ten egg-tubes opening ventrally either between the eighth and ninth (*Terebrantia*) or between the ninth and tenth (*Tubulifera*) abdominal segments. In the male there are two testes, opening between the ninth and tenth segments; accessory glands are also present.

Reproduction is of two forms—bisexual and unisexual, or parthenogenetic. In the case of those forms with two sexes, the females are always more abundant than the males. In some species one male fertilizes a number of females. The bisexual is the normal and commoner mode of reproduction,

but parthenogenesis is of frequent occurrence, a number of species, as far as is yet known, reproducing entirely by this method. The female lays from 25 to 100 eggs, singly, either in the tissues of the plant, if she has an ovipositor, or on the surface, if she does not possess one. The process of oviposition is as follows—the ovipositor is bent down till at right-angles to the abdomen and then gradually inserted into the tissues. By successive contractions of the abdomen, the eggs are pushed down between the valves of the ovipositor. The eggs, though usually laid in the tissues of the leaf, may be deposited in almost any region of the plant, except the petals ; they are delicate and colourless as a rule, sometimes yellow or brownish, and either elongate-oval or bean-shaped. The length of the egg-stage is from three to fifteen days, varying considerably, even in the same species, according to the weather conditions. The newly hatched nymph begins to feed immediately, and as in the case of Aphids, the head at this stage is very large and the mouth-parts well developed. During the process of growth the thorax and abdomen develop considerably in size, but the head remains much the same. The eyes are not compound, consisting only of a few separate facets. The number of moults varies from three to five, but the usual number is five, the first two instars being the so-called " larval " stages, when the nymphs are active and feeding all the time. In the second instar the growth in size is noticeable and the facets of the eyes greatly increase in number. The first and second instars are of about equal length. The third instar constitutes the " propupal " stage, when the nymph ceases to feed, selecting some spot in the shade, such as the under side of the leaf, and hardly moving from that position all the time. It differs from the second instar form in having distinct wing-lobes. At this stage in some species the nymph descends into the soil for " pupation." In the fourth or " pupal " instar the nymph is still non-feeding and immobile, and is distinguished from the preceding stage by having the wing-lobes longer and the antennæ bent back over the head, to facilitate moulting to the adult. The propupal and pupal stages generally last only a few days each. In the adult stage or fifth instar, feeding is recommenced. During the process of feeding, the mouth-parts are driven into the plant tissues

by a series of downward and inward jerks of the head, by which means the cells are pierced and lacerated, so that a "mush" of cell-sap and tissue is formed. The mouth is then closely applied to the puncture and the mush sucked up into the pharynx. On account of its short structure, the mandible is believed to start the puncture in the hard outer tissues, while the longer and more slender maxillæ are used to penetrate the softer substance below. By this surface-feeding, white spots and areas are produced on the leaf, caused by the air in the evacuated epidermal cells. In some species, in the nymphal stages, the liquid excreta collects into a drop on the end of the abdomen, and is finally deposited on the plant, where it hardens, adding to the unsightly appearance already produced and possibly acting as an attraction to certain fungi.

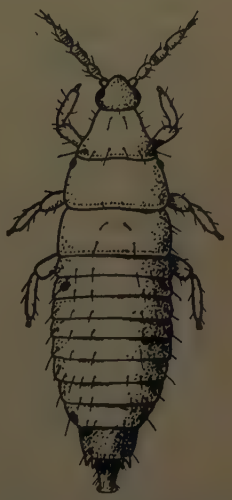


FIG. 56.—Larva of *Tæniothrips pyri*. (× about 60.) (After Moulton—slightly simplified.)

Hibernation takes place either as a nymph or an adult, in dead grass or dried plant stems, and may be in the place of feeding, in the soil, in lichens, fungi, etc. The number of broods in a year numbers from one to a dozen or so, but the number also differs in the same species according to the climate of the locality, whether temperate or tropical. Propagation of the species is evidently carried out by the winged female, which flies to a fresh plant and lays her eggs there.

The food-plants of Thrips are very varied, consisting of most flowering and some flowerless plants, including many fruit trees, grasses and cereals, and many vegetables, and certain crops such as cotton and tobacco. Some Thrips are not herbivorous, but feed on mites and certain insects; one has been observed to feed on the eggs of a Curculionid, and another on a species of Aleurodid.

Thrips suffer from a variety of natural enemies. These include the adult of *Triphleps insidiosus*, Say., an Anthocorid, which feeds on adult Thrips, while its "larva" preys on their

nymphal stages. A Chalcid parasite, *Thripoctenus russelli*, is recorded. Chrysopid and Syrphid larvæ, Coccinellids and spiders serve to keep them down. They are also parasitized by *Acarina*, Gregarines and Nematodes, and certain fungi.

The most important literature on this order includes the works of J. Uzel (1895), Monograph of the Thysanoptera; R. S. Bagnall (1908 and 1911), British species; Dudley Moulton (1909), Pear Thrips; H. M. Russell (1912), Bean Thrips; A. Petersen (1915), Head and Mouth-parts; C. B. Williams (1915), Pea Thrips; W. E. Hinds (1902), Monograph of the N. American species.

The number of British species recorded up to the present is about 100; but new ones are constantly being added.

Thrips constitute many serious pests on fruit, crops and other plants. They injure plants by external damage to the tissues, stopping the growth of the plant, causing wilting, and sterility of the seed. By their constant extraction of sap and chlorophyll granules from the leaves, the Thrips interfere with the normal metabolism of the plant, the process of photosynthesis is hindered, and after a while the leaves turn yellow, wilt and drop off. By the leaf scars thus formed and the wounds caused by feeding, fungal spores and bacteria enter the plant and add to the destruction of tissues already caused by the Thrips. Thus in a short while, in some cases, the whole plant is killed outright. When the young seed is pierced by the mouth-parts, the embryo is killed and germination is prevented. Among the chief pests are the Citrus Thrips (*Scirtothrips citri*), which attacks oranges, grape-fruit and lemons in California and Europe; the Onion Thrips (*Thrips tabaci*), attacking onions in U.S.A., West Indies, and Tasmania, and tobacco in Russia. The Pea Thrips (*Kakothrips robustus*) damages peas and beans in England and West Europe. The Greenhouse Thrips (*Heliothrips hæmorrhoidalis*) attacks ornamental plants in Europe and America, oranges in Italy, and eucalyptus in Australia. *Æolothrips fasciatus* attacks wheat, etc., in Europe and N. America. The Cocoa Thrips (*Physopus rubrocinctus*) is a pest on cocoa in Africa, West Indies, and Ceylon.

Thrips are a group of insects which can be really effectively dealt with by spraying; a good contact spray such as Rosin Wash should be used.

The *Thysanoptera* were for many years divided into two sub-orders, but in 1911 Bagnall added a third, the *Polystigmata*. Thrips are classified as follows :—

I. Eleven pairs of spiracles. Hind pair of coxæ most widely separated. Palpi one-jointed.

POLYSTIGMATA. Antennæ seven-jointed. Ninth abdominal segment elongated. Ocelli and wings absent. No ovipositor. Closely resembling *Tubulifera*. One family—*Urothripidæ*.

II. Not more than four pairs of spiracles present. Intermediate coxæ most widely separated. Palpi never less than two-jointed.

TUBULIFERA. Labial palpi two-jointed. Maxillary palpi two-jointed. No ovipositor. One family—*Phleothripidæ*.

TEREBRANTIA. Ovipositor present. Two families.

Thripidæ. Labial palpi two-jointed. Maxillary palpi two- or three-jointed.

Æolothripidæ. Labial palpi two-, four- or five-jointed. Maxillary palpi three- to seven-jointed.

ANOPLURA

Sucking lice.

Body flattened dorsally. Head large and distinct. Thorax with little sign of segmentation; sometimes fused with the abdomen, which is segmented.

The *Anoplura*, to which the name of "Sucking Lice" has been given as a distinction from the *Mallophaga* or "Biting Lice," are a group of small insects parasitic on the bodies of mammals. They are widely distributed, being recorded from both temperate and tropical regions.

They are about 3–4 mm. long, somewhat flat, elongate-oval in form and greyish of colour: these features, together with the situations in which the lice are found, render them easy of recognition. The main characters in which they differ from the *Mallophaga*, which, though chiefly infesting birds, are also found on mammals, are: the head, though equally distinct, being smaller, and furnished with a sucking proboscis in place of biting jaws; the thoracic segments being less clear and showing very little segmentation, while the claws in most cases are larger.

The head is large, and distinct from the thorax. It bears short antennæ, usually five-jointed. The eyes, wanting in some cases, are usually black and fairly prominent. The mouth-parts are formed for sucking. They consist of a dorsal and ventral stabbing organ lying in a sac or blind pocket, situated below the pharynx and œsophagus; the pharynx is divided into two regions, termed the first and second pharynx: the first pharynx becomes tubular as it nears the entrance to the mouth, where are situated a series of sharp, chitinous, backwardly directed hooks. The two stabbing organs very possibly consist of the modified maxillæ and labium. They are long and flexible, the upper one with a double groove along the greater part of its length, and the lower one with a single groove down its centre, and a three-pointed apex. When in a feeding position, the tubular portion

is thrust slightly forward; this action brings the hooks, pointing outwards, into a fringe round the mouth, and enables them to be fixed in the skin of the host: the stabbing organs are then pushed forward into the skin, and saliva from glands situated far back in the thorax flows down the channel formed by the union of the two grooves: the blood of the host is not drawn up through this channel, but is sucked up through the pharynx.

The thorax is a solid mass, the three segments being scarcely discernible. The legs are strong and of medium length, with one-jointed tarsi, fitted with a large claw folding back on the tarsus.

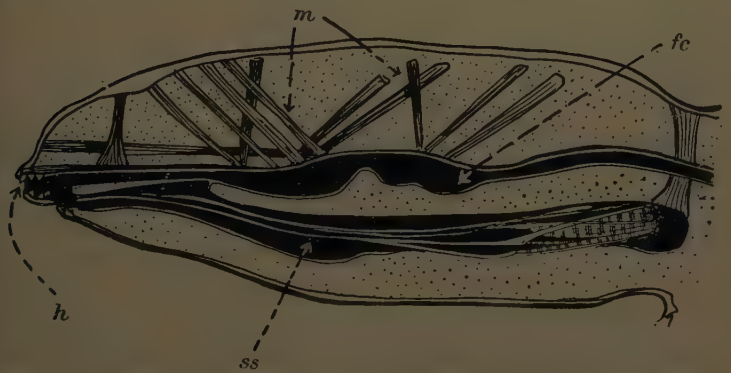


FIG. 57.—Diagram of mouth-parts of *Pediculus* in longitudinal section.
(Modified from Peacock.)
ss = stabber sac, with dorsal and ventral stabber and the salivary duct. *fc* = food canal. *h* = backwardly directed hooks. *m* = muscles for the expansion of the roof of the pharynx.

The abdomen consists of eight segments of which the apical two are fused. There is a spiracle on segments two, three or six to eight. The apex of the abdomen is pointed in the male and more or less cleft in the female.

From the sucking pharynx a narrow tube or gullet leads into a very large stomach, from which a short, narrow intestine leads to the rectum and anus. There are eight Malpighian tubules. There is a small brain, connected to the sub-œsophageal ganglion lying just below the stabber sac by two nerve cords. A single nerve cord connects the sub-œsophageal ganglion to the thoracic ganglion, from which nervures run laterally and posteriorly to the legs and abdomen.

The reproductive organs are simple. The female has a pair of ovaries, each ovary consisting of five long tubes with ova in various stages of development. On its way through the oviduct each egg is coated at its base with a portion of cement which emanates from glands connected with the oviduct. This cement fixes the egg to the cloth or hair on which it is laid.

The male organs consist of a pair of testes, each divided into two parts; a narrow tube connects each testis with the seminal vesicle, from which a narrow duct passes to the penis.

The eggs are ovoid in shape, and have at the larger end a sort of lid or operculum, circular in shape and sculptured in the form of small nodules. The situations chosen for oviposition are cloth, fibres, or body hairs, to which the eggs are attached by means of the cement accumulated on them during their passage through the oviduct. Nuttall states that the female is assisted in oviposition by the gonopods, which clasp the hair or cloth fibre and direct the placing of the egg: it is noticed that almost without exception the eggs are laid with their length parallel to their support. When laid, the eggs are creamy white and somewhat transparent, becoming more yellow and opaque as they mature. When the emergence of the young louse is due, air passes through the operculum and down through the mouth of the louse, coming out at the end of the body, and filling the hinder portion of the egg, gradually but surely pushes the louse forward until its head presses the operculum open and its legs become free to grasp the supporting hair and enable the louse to pull itself clear of the egg.

Fig. 58.—*Phthirus pubis.* (× 15, about.)
(Simplified from Denny.)

The newly emerged louse is whitish and has delicate integument; in other respects it much resembles the adults. Three

moults are effected during a period of from eight to eleven days. It is not till after the third moult that the external sexual characters are discernible. In normal conditions young lice start to feed within an hour of hatching, and if unable to obtain nourishment for twenty-four hours, die. The method of feeding is simple: the fringe of teeth round the edge of the mouth are fixed into the skin of the host, forming a leverage against which the louse is enabled to force its stabbing organ into the flesh; saliva flows down the channel formed by the two stabbing organs, and, mixing with the blood of the host, stimulates its flow to the wound and prevents it from clotting; the blood is then sucked up through the pharynx. The pumping action which causes the blood to flow up the pharynx is, in fairly transparent specimens, plainly visible as an expanding and contracting movement which also continues in waves along the alimentary canal.

In the case of *Pediculus*, egg-laying commences two or three days after maturity has been reached and extends over a period of from twenty to thirty days; six to ten eggs being laid per day. The average life of a male louse is four weeks, and of a female five weeks. Lice are fairly active, but must have warmth to enable them to live. They are found wherever there are poor, overcrowded conditions and lack of proper cleanliness.

FIG. 59.—Eggs of Hog Louse on bristle. (×30, about.)

Dalla Torre, in his classification of this order, divides it into four families:—

A. Legs not provided with clasping claws; tibiæ and tarsi slender, the latter without any thumb-like process. Mouth at the extremity of the long tubular process. *Hæmatomyzidæ*. Antennæ five-jointed. Including the Indian Elephants' Louse (*Hæmatomyzus elephantis*).

B. Legs with clasping claws; tibiæ stout, with a thumb-like process. Antennæ three- to five-jointed. Body

flattened. A stigma on the mesothoracic and abdominal segments three to eight.

Pediculidæ. Eyes large, dark, prominent.

Hæmatopinidæ. Eyes obscure or absent.

C. *Echinophthiriidæ*. Antennæ four- to five-jointed. Body thick and plump. A stigma on the meso- and metathoracic and abdominal segments two to eight. Head wide, eyes absent. Body sometimes covered with thick spines.

Hæmatopinidæ contains the lice most commonly found on animals such as rats, pigs, elephants, etc.

Echinophthiriidæ is made up of three somewhat aberrant genera, the species of which infest seals and walrus.

The *Pediculidæ* is split up into two sub-families: *Pediculinæ* and *Pediculinæ*. The *Pediculinæ* occur on monkeys, while the *Pediculinæ*, of greater importance than any of the other families, contains the species parasitic on man, and is divided into two genera, *Pediculus* and *Phthirus*. *Pediculus* contains the body louse (*P. humanus*) and the head louse (*P. capitis*). *Phthirus* contains the crab or pubic louse (*P. pubis*).

The most important work on the classification has been done by Dalla Torre, 1909 (*Genera Insectorum*, Fasc. 81).

Much work has been done on this family, both in its morphological and economic aspects: Cholodkovsky (1903), Enderlein (1904), Neumann (1909), Kellogg and Floyd (1915), Cummings (1916), Peacock (1916, 1918), Bacot (1907), Harrison (1916), Nuttall (1917, 1918), Lloyd (1919), Florence (1921).

Apart from the unpleasantness caused by their association with man, lice have to be considered in a far more serious aspect, it having been proved beyond all doubt that they are the transmitters of typhus, trench fever and relapsing fever. During the early part of the Great War lice became a serious factor against the welfare and success of the troops, and it was discovered that they were the agents in the spreading of trench fever; while in the prison camps of Germany the cases of typhus and relapsing fever were terribly increased by their aid. Among the civil population also the presence of lice

has for long been a problem. In areas where bad housing and poor, overcrowded conditions exist, lice appear and multiply exceedingly. The heads of children, unwashed and uncared for, become infested with *P. capitis*; while the body louse, and to a less degree the crab louse, breed in the clothing and on the bodies of man. Should typhus break out in such conditions, its rapid spread would be an easy matter. Better housing and increased facilities for personal cleanliness will do much towards the eradication of these dangerous insects.

RHYNCHOTA (*Hemiptera*)

Bugs, etc.

Two pairs of wings; mouth-parts formed into a rostrum, containing fused stylets, without palps. Antennæ simple, usually two to ten joints. No metamorphosis, the wings developed as lobes outside the body.

In the main, this group is recognizable at sight by the mouth-parts; the wings differ so much that, while useful for recognition of sub-orders or families, they cannot be shortly defined as a character of the order. Colour is largely cryptic, green, brown, dead-leaf, black, according to the habitat: in some, violent warning colouring; in the smaller forms, there is no colour scheme.

The head is well developed, usually free, in some forms sunk in the thorax, in the Coccids not distinct; the antennæ vary from the tiny bristle of the *Homoptera* to the long, free feelers of the Coreids. In the aquatic forms they are short, and lie in grooves of the head.

Compound eyes develop in the nymphs and two or three ocelli: the adult degenerate female (*Coccidæ*) may have only ocelli.

The mouth-parts are extremely uniform and characteristic. The mandibles and maxillæ form fine stylets which unite in the groove of the labium, constituting a single fine piercing organ. The two interior portions (maxillæ) form a dorsal and ventral duct. The outer portions (mandibles) are locked to the inner portions, but have a sliding motion along them. The labrum is short, lies over the labium and covers it dorsally only at the base. The labium may be very short as in Coccids, or long and jointed as in Pentatomids. It is straight, stretching as far as the hind coxæ, or farther in the herbivorous *Heteroptera*, short and curved in the predaceous Reduviids and aquatic *Heteroptera*. No palps occur. The mouth-parts function as a sucking apparatus with the sucking pharynx and as a saliva injector actuated by the salivary pump situated

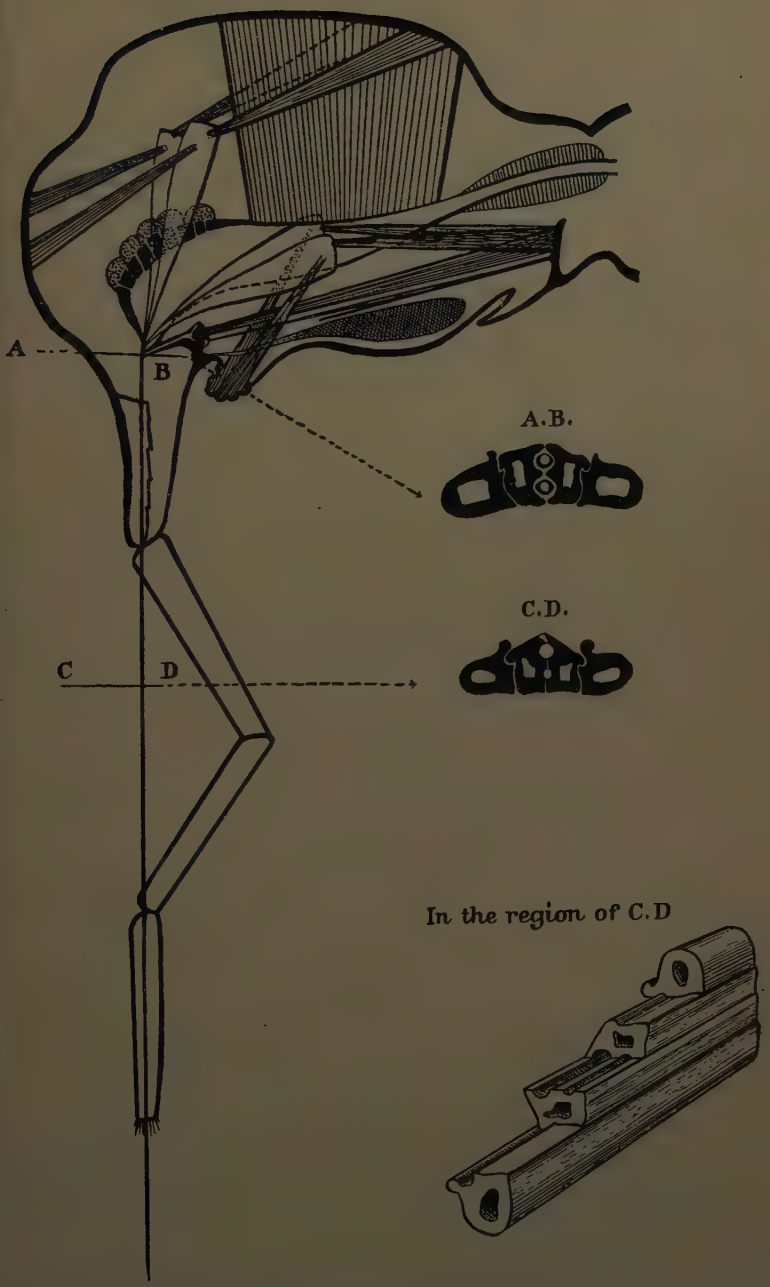


FIG. 60.—Diagram of *Hemipterous* mouth-parts. Shows the appearance, if it could be seen in perspective, with successive layers removed.

in the head. In most the piercing portion is pushed outwards and inwards by muscles in the head, but in Coccids the joint mandibles and maxillæ are so long that they lie in a vertical sac in a long loop, and the actual muscular apparatus that inserts them into the plant and retracts them appears to be in the short labium. (Awati (1913), Davidson (1913).)

The prothorax is large, distinct, and sometimes spined. The mesothorocic scutellum is very large in Pentatomids. Wings in *Heteroptera* lie flat on the abdomen, the first pair thickened at the base and lying across each other. In *Homoptera* they lie at an angle, not crossing, free of the abdomen, and are of one thickness. They vary in the last four families. The second wings are large, hyaline, and folded longitudinally. Neither pair of wings are functional in some forms, but in most both pairs function in flight.

There are usually eight visible abdominal segments. Spiracles

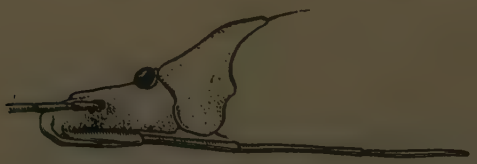


Fig. 61.—Head of a Pentatomid, showing the herbivorous type of rostrum.

occur on the thorax and six or seven abdominal segments. These are reduced in number in *Aleurodidæ* and *Coccidæ*. The aperture of a stink-gland is found on the metasternum of some adult forms, and in these species usually on the third and fourth abdominal tergum of the nymph. Legs are usually of the running type, the hind-legs for swimming in the aquatic forms, the fore-legs for digging in the Cicada nymphs. They may be absent in female Coccids. In Fulgorids, Cercopids and Jassids the hind-legs are formed for leaping.

There is no simple means of sex differentiation in many families of the *Heteroptera*: Capsids, the aquatic *Heteroptera*, the *Homoptera* have a large retracted ovipositor, easily seen. Male Coccids often have a large penis. Except in the last family, there is little sexual dimorphism.

The alimentary canal is marked by the sucking pharynx, absence of gizzard, and otherwise simple character. Salivary

glands and receptacles are well developed. The tracheal system is normal, reduced only in the Coccids and Aleurodids. The nervous system is not concentrated, and the sense organs are limited to eyes, ocelli, taste and touch hairs, and a large taste plate just anterior to the pharynx. Sound production is a feature only of Cicadids and Corixids, and definite sound-perceiving organs are probably limited to simple chordotonal organs in the aquatic *Cryptocerata* and possibly in Cicadas

Fig. 62.—Head of a Reduviid, showing the carnivorous type of rostrum.

The life-history is uniform in all but the Coccids, Psyllids, Aleurodids and Aphids. Eggs are laid on or in plants. There are five nymphal instars with wing-lobes in the last two. Adults are of both sexes; the life of the imago is long, reproduction occupies a considerable time, and there is little difference in habits between nymph and adult. Hibernation is usually as an adult, but this does not hold with Coccids, Aphids, etc. Nearly all fall into one of four groups:

(*a*) Active forms, found by day on plants; herbivorous or carnivorous.

(*b*) Active nocturnal forms, herbivorous.

(*c*) Aquatic diurnal carnivorous forms, which fly at night.

(*d*) Parasitic forms living in colonies on plants, with more or less modification of structure and life-history in accordance with the degree of immobility.

Food is the liquid extracted from plants, the blood of mammals, the liquid extracted from insects.

Checks include egg parasites (Chalcids), Dryinids, *Strepsiptera*, Tachinids and other nymph parasites, as well as Coccinellids, Syrphids, Chrysopids, Hemerobids, in the case of the smaller inactive species.

An unusual feature, in the *Homoptera*, is an organ called the pseudovitellus or mycetoma, whose function is not known. It contains organisms similar to yeasts. Sulc, Pierantoni and Buchner have written about these, and there is evidence of a symbiotic relationship, beneficial to both. The organ

and its flora is inherited. In some families it is a large and conspicuous part of the abdomen.

This order is widespread, both in the tropics and temperate regions. It includes a great number of species. Lethierry and Severin catalogued *Heteroptera*. There is a special literature on *Coccidæ* and *Aphidæ*, and individual families must be consulted for monographs. The authorities include Distant, Kirkaldy, Bergroth, Stal, as well as special authorities on the *Coccidæ* and the like. Except the last four families, there is not a great literature apart from purely systematic works. The

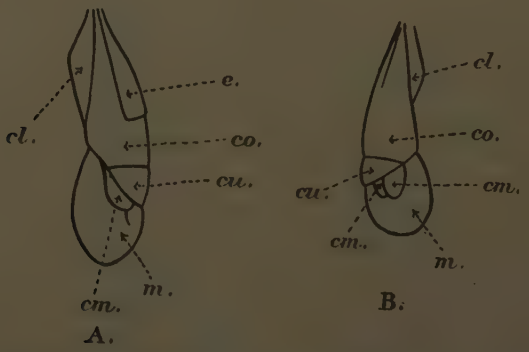


FIG. 63.—Wings of Hemiptera. A. Anthocorid. B. Capsid.
cl = clavus. *e* = embolium. *co* = corium. *cu* = cuneus. *cm* = cells of membrane. *m* = membrane.

group is uniform, with little diversity of habits, and not attractive to entomologists. Catalogues and similar reference books are therefore few.

The economic importance is due to the great number of plant-sucking species, which are now being identified as carriers also of plant disease. The important families are Pentatomids, Lygæids, Pyrrhocorids, Tingids, Capsids, and the whole *Homoptera*. Coccids and Aphids are the two most important families. *Cimicidæ* include the Bed Bug, probably a carrier of disease in man. *Reduviidæ* are mainly beneficial as preying on other insects, but some may transmit disease in vertebrates.

Butler (1923) has dealt at length with the Biology of the British *Heteroptera*.

Sub-Order I. *HETEROPTERA*

Base of hemelytra thickened. Front of head not touching fore-coxæ. Rostrum free.

(*a*) GYMNOCERATA

Antennæ conspicuous.

Pentatomidæ.

Shield bugs.

The mesothoracic scutellum large, covering the abdomen to the middle point or wholly.

This large family is easily recognized. In size the species vary from a quarter of an inch to over an inch. Colouring is cryptic (greens, browns, dry-grass colouring and the like), or violently warning. The colour scheme may vary with each instar. The body is usually flat: the antennæ are well developed; wings and tegmina are used in flight, but the latter may be absent in the forms which have the scutellum covering the body. Sex recognition by external characters is usually impossible.

Fig. 64.—Shield Bug (Pentatomidæ), *Zicrona interstinctum* L.

The life-history is that of the group. The eggs are upright, shaped like a barrel, with an upper lid. They are laid in clusters on the plant. Habits divide the group into three: the common tropical ones live in the open on plants, in all stages; the less common ones live on plants, but feed on caterpillars; the still less common species, which may become enormously abundant, live by day in the soil and emerge at night. Some mimic Scarabeids very closely, and have well-developed burrowing legs. Scent production is a common protection.

The sub-families of the *Pentatomidæ* have been monographed by Schouteden in *Genera Insectorum*, Fasc. 24 (1904 and 1906), 30 (1905), 52 (1907) and 153 (1913).

There are thirty-eight British Pentatomids.

A few species are of economic importance when numerous; they are included in the following genera: *Antestia* spp. are pests of coffee bushes. *Bagrada* attacks crucifers, as does also *Eurydema* and *Murgantia*. Wheat is attacked by *Chlorochroa* and rice by *Nezara* and *Podops*. *Dolycoris* is injurious to sunflowers. Cotton is attacked by *Pentatoma*.

Coreidæ.

Leaf-footed bugs.

Antennæ inserted above a line drawn from the eyes to the base of the rostrum. Scutellum small. Rostrum not curved.

This is a large and widely distributed family of insects ranging in size from a quarter to one and a half inches: many are broad and somewhat heavily built, while others are more slender. Bright colouring is not often seen in this family, the majority of its members being dull brown or green, in many cases resembling dried leaves or grass.

The head is small and set somewhat deeply in the prothorax. The antennæ are four-jointed and moderately long; the rostrum also is four-jointed. The large prothorax and the abdomen are often furnished with lateral spine-like processes. The legs, especially the posterior pair, are in many cases expanded in a leaf-like fashion, a feature which gives rise to the name of "leaf-footed bugs." The hemelytra cover the wings, which are often used. The dorsal surface of the abdomen, only seen when the insect is in flight, is in many cases brightly coloured.

The life-history is typical of the group. The eggs are of two types: (1) oval and flattened, without ornamentation; (2) more elongate, upper surface not flattened. They are laid in clusters on the plant. The resulting nymphs undergo five moults before attaining maturity; the wing-lobes do not

appear until the third moult. Stink glands are present in the nymphs on the dorsal surface of the abdomen. The habits of nymphs and adults are similar, both being feeders on plant-sap.

Twenty-four species are found in Britain.

Fig. 65.—A Coreid (about nat. size).

This family is not of great economic importance; a few species, however, are recorded as pests. Cucurbitaceous plants are attacked by species of *Anasa* and *Leptoglossus*; pulse crops by species of *Clavigralla*, and species of *Leptocorisa* infest rice.

Berytidæ.

Like Coreidæ, but with long legs; the apices of the femora knobbed.

This family consists of a few insects of delicate and slender build. They bear considerable resemblance to the smaller Coreids, but may be distinguished from them by the longer

legs and the knobbed apices of the femora. The colouring is usually unobtrusive.

Up to the present they have been somewhat overlooked, and little is known of their life-history; but it is reasonable to suppose that their habits are similar to those of the Coreids.

There are eight British species of no economic importance.

Lygæidæ (*Myodochidæ*, *Colobathristidæ*).

Antennæ inserted on the side of the head. Ocelli present.

A large family, widely distributed throughout the world. Many of these insects cannot easily be distinguished from many of the smaller Coreids; but as a rule the antennæ are obviously inserted on the sides of the head, nearer the eyes than in the Coreids. The venation of the membranous part of the hemelytra also differs, for in the Lygæids there are two basal cells which are wanting in the Coreid venation. Large size is not a characteristic of these insects, few being over half an inch in length. The colouring is variable, in some cases being vividly warning, and in others, dull, cryptic brown or grey.

The head is of moderate size, with compound eyes, two ocelli and fairly long antennæ. The rostrum is straight. The legs are long. Sex recognition by external characters is very difficult, if not impossible.

The life-histories of few species have been worked out. Oval eggs are laid in clusters, either on the soil or on the food-plants. Some species are undoubtedly plant-feeders, and a few are known to be predaceous: but the habits of the majority remain a matter of conjecture. Both adults and nymphs are found in a variety of situations: in grass and low herbage, among fallen leaves, and on tree trunks, in some cases.

There are sixty-six British species, all of which are small, dull-coloured forms.

There are a few Lygæids of economic importance, such as species of the genus *Blissus* which attack wheat. *Oxycarœnus* and *Oncopeltus* are serious pests of cotton as they not only suck the seeds, but stain the lint with their excreta.

Pyrrhocoridæ.

Like Lygæidæ, but without ocelli.

This family contains about 300 species, widely distributed throughout the world. They are as a rule larger, from a quarter inch to two inches in length, and more brightly coloured than the Lygæids, to which in general characters they are similar. The chief point of distinction between the two families is the absence of ocelli in the Pyrrhocorids. In several species the membranous portion of the hemelytra is either much abbreviated or entirely wanting, and the wings also are absent. External sex recognition is difficult, except in the case of *Lohita grandis*, in which the male has an abdomen of about twice the usual length, and very long antennæ.

As far as is known the life-history is more or less that of the group. Eggs are laid on plants or on the bare ground. Both nymphs and adults are, as far as can be ascertained, plant-feeders, and may usually be seen feeding openly on the food-plants. The number of broods a year varies according to species and climate. One species is gregarious and has been found living together in great numbers in depressions on the bark of trees. *Dysdercus cingulatus* also is often found living gregariously on the silk-cotton plants in India. In common with Lygæids, Coreids, etc., Pyrrhocorids possess glands which secrete an odoriferous fluid.

There is only one British species, belonging to the genus *Pyrrhocoris*.

Regarding economic importance, the only species which can really be termed pests are contained in one genus (*Dysdercus*). These few species are known as the "cotton stainers" and do considerable damage to the cotton in the bolls by staining it a reddish tinge with their excreta. It is also thought that they stain the cotton fibre before the boll opens, by introducing a fungus through the medium of the rostrum. There are about twelve species of these "stainers," of which perhaps the most important are *D. cingulatus* in India, *D. ruficollis* in the West Indies, and *D. suturellus* in U.S.A.

Tingidæ.

Lace-wing bugs.

Hemelytra reticulate. Pronotum usually with reticulate markings extending on lateral leaf-like expansions. Tarsi two-jointed.

A family of moderate size and fairly wide distribution. Tingids are inconspicuous little insects, few of them attaining a length of a quarter of an inch. In spite of their dull colouring they will, on closer examination, be found to be very beautiful, owing to the intricate reticulation of the hemelytra, a feature giving rise to the name of "lace-wing bugs."

The head is small and in many cases covered by the pronotum, which usually has lateral, leaf-like expansions, gracefully reticulated. With the exception of one genus (*Piesma*), the pronotum extends down over the scutellum, concealing it. *Piesma* is also the only genus in which ocelli are present. The third joint of the antennæ is usually very long, and the apical joint is frequently somewhat clubbed. The rostrum, when at rest, lies in a deep groove.

All, so far as known, are plant-feeders. Some species are gregariously inclined. The eggs are usually laid on plant tissues; the nymphs feed openly on the plants.

There are twenty-two British species.

Economically this family is of little importance, there being but few species recorded as pests. *Tingis pyri* attacks pear in Europe, and members of two genera, *Leptobyrsa* and *Stephanitis*, damage the leaves of rhododendrons.

Aradidæ.

Broad, flat insects. Scutellum long. Abdomen projecting beyond at the sides. Tarsi two-jointed.

This family, which has a wide distribution in both temperate and tropical regions, consists of about 300 flat, obscurely coloured little insects. They are all easily recognized by the fact of their flatness and having the apex and sides of the

abdomen extending beyond the hemelytra and being visible from above. The colouring is black or brown.

The antennæ are four-jointed, somewhat short and thick. There are no ocelli. The scutellum is rather long and the abdomen is often sculptured. The fore-legs are inserted on the disc of the prosternum. The hemelytra lie flat on the abdomen, but, as stated above, do not entirely cover it.

The habitat of both nymphs and adults is usually under bark, but they have also been found in decaying wood, under stones, or among fallen leaves. Little is known of the life-history. The nymphs are in some cases more brightly coloured than the adults; an instance of this may be seen in *Aneurus lævis*, a British species. A definite statement as to the food-habits cannot yet be made, but fungus growths under bark, etc., probably form the greater part of their diet.

There are six British species.

Hebridæ.

Small. Body clothed below with dense, silvery pubescence. Antennæ five-jointed.

This family contains only about a dozen species, all of which are very small and inconspicuous. The silvery pubescence on the underside of the body should render these insects easy to recognize, as they differ from the Hydrometrids in having five-jointed antennæ.

Little is known of the life-history and habits. They are usually found in wet moss.

There are two British species, both belonging to the genus *Hebrus*.

Hydrometridæ.

Antennæ four-jointed. Tarsi two-jointed. Body clothed beneath with silvery, velvety pubescence. Live on the surface of water.

This family contains some 160 species, widely distributed throughout the world. They vary considerably in form, but are all of dull colouring, being usually grey, black, or yellow-

ish. Some are quite small; others are over an inch in length; the majority are elongate and narrow.

In most cases the antennæ are long and the eyes well developed. The rostrum is short and curved. Nearly all are winged, and the hemelytra are usually without any membranous portion. In the genus *Halobates* both hemelytra and wings are absent, and the meso- and meta-thorax are very closely united, forming the major part of the body, the abdomen being very small. Generally the abdomen is of normal structure, and the body is clothed beneath with a dense,

FIG. 66.—*Gerris sp.* (× 2.)

silvery pubescence of a velvety nature. The legs are usually long, especially the intermediate and posterior pairs; in some species they are very long. The fore-legs of some species are prehensile.

These curious insects live on the surface of the water in ponds and streams. The majority have the unusual habit of walking and running on the surface film without breaking through. Some species drown if submerged; others are able to go beneath the surface, taking a supply of air with them. They sometimes leave the water, walking on plants by the bank. Some are very active, others more sluggish. They are

predaceous, feeding on small insects that chance to fall into the water.

The eggs are usually encased in a gummy secretion and attached to the stems of submerged plants.

The genus *Halobates* is entirely marine; specimens have been found on the surface of the sea 500 miles from the land. In rough weather these insects are said to go below the surface. Their food is either recently dead organisms or the smaller forms of jelly-fish. Eggs have been found laid on a floating feather, and in one instance a female has been found with eggs attached to her body.

There are fourteen British Hydrometrids.

Henicocephalidæ.

Head long, divided into two distinct lobes. Rostrum short, curved. Hemelytra membranous throughout, conspicuously veined.

A small but widely distributed family of one genus, containing about a dozen species. They are small, elongate insects allied to the Reduviids, but may easily be distinguished by the curious formation of the head, which is swollen, globe-like, behind the eyes. Ocelli are situated on this globular part: the antennæ are placed on the front portion. The rostrum is short and curved. The somewhat large hemelytra are membranous throughout and distinctly veined.

Judging by the shape of the rostrum, these insects are probably predaceous. They have been found in damp, decaying vegetation. Westwood says they are inclined to be gregarious, and have been seen dancing in the air, like midges.

There are no British representatives, the nearest species occurring in Southern Europe.

Phymatidæ.

Fore-legs short and stout, femur broadened, tibia curved and pointed, pressed tightly against femur. Tarsi absent in some cases.

This family, which is fairly widely distributed in both temperate and tropical regions, contains from 90 to 100

species. They are very curious insects and little is known about them.

The structure of the fore-legs is very unusual, especially in some forms in which the tibia is articulated to the femur in such a way that a pincer-like structure is the result; in these forms, as well as in some others, the tarsi are wanting. In some species the fore-legs are raptorial. The intermediate and posterior legs are of normal character. The eyes are large and somewhat prominent. The pronotum and sides of the abdomen of some species are furnished with spines.

It is believed that these insects are predaceous, and indeed one species at least is known to capture and suck honey-bees. There are no British species, the nearest occurring in France.

Reduviidæ.

Rostrum curved, usually stout, not closely pressed to the prosternum. Head usually elongate.

A large family containing some 2,000 species, widely distributed in both temperate and tropical regions.

Reduviids are usually about half an inch in length, but many are only a quarter of an inch long, while others may attain the length of an inch. In colour they are either dull or vividly warning, many being bright red and black. They vary greatly in form, some resembling other bugs such as Coreids, Pyrrhocorids, Lygæids, while others are very like certain flies, ants, etc.

The head is usually long, with a short, somewhat stout three-jointed rostrum, which is curved, and not pressed closely against the prosternum. The compound eyes are placed at a considerable distance from the pronotum. Ocelli, when present, are placed behind the eyes. The antennæ, usually of moderate length, are sometimes very long, and in some cases hairy. The prothorax is well developed and often bears a transverse constriction in the middle. The hemelytra consist of three divisions and wings are usually present; but some females are wingless. The legs vary considerably; in some species, which resemble flies such as Tipulids, they are very long and slender, and in many cases hairy. Some forms have

the femora and tibiæ spined, while the fore-legs are often dilated and spined.

Although so large and curious a family, little is known of the life-history. As far as has been ascertained, eggs are laid in clusters on plants, etc. They are cylindrical, with a lid at one end for the emergence of the young Reduviid. It is said that in Brazil the nymphs of the genus *Ghilianella*, which are of very slender form, are carried about by the female, the elongate nymphs curling their abdomen round her body. The nymphs of one of the British species, *Nabis lativentris*, greatly resemble ants, with which they run about on plants.

Fig. 67.—Typical Reduviid (about nat. size).

The majority of the Reduviids are predaceous, catching other insects and sucking their juices. A few species are believed to be herbivorous. Many emit an odour, more or less unpleasant, and some of the more powerful forms are possessed of a somewhat poisonous bite, and do not hesitate to attack man. Some species of the genus *Conorhinus* are found in houses, where the young have been seen with a covering of dust, etc., adhering to the body. These may have an importance in the transmission of disease organisms. Reduviids are, as a rule, both diurnal and nocturnal of habit. Hibernation usually takes place in the adult stage.

There are eighteen British species.

On account of their predaceous habits Reduviids are possibly beneficial.

Saldidæ.

Rostrum curved, long. Ocelli placed between the eyes.

A family of about 100 species, fairly widely distributed. Saldids are dark-coloured, active little insects, with a long,

curved rostrum and prominent eyes, between which latter, ocelli are placed. The scutellum is large. The hemelytra, which entirely cover the abdomen, are without a cuneus.

These little insects lead a semi-aquatic life in wet moss and material of a similar nature. They are very active, and may often be seen running and jumping about on wet mud. They are able to fly, and some species are attracted by light. Nothing is known of the earlier stages. There are nineteen British species, all of which belong to the genus *Salda*.

Aëpophilidæ.

Head short. Hemelytra short, wings absent. Marine.

One species, *Aëpophilus bonnairei*, comprises this family. It is a small insect, spending the greater part of its life covered by the sea (c.f. *Aëpus*, *Carabidæ*). It has a very short head, without ocelli. The hemelytra are very short and wings are entirely absent. It occurs most frequently on the shores of Western France, where it is nearly always covered by the water. It very possibly lives on small soft marine animals or on *Algæ*. It has been found on the South Coast of England and the East Coast of Ireland.

Ceratocombidæ.

Hemelytra with cuneus and embolium. Antennæ with the two apical joints long and slender, with long hairs.

This is a small family containing about thirty minute species. The head is somewhat prolonged in front, with the eyes set rather far back. Ocelli are present. The tarsi are three-jointed.

Little is known of the habits or life-history. The adults have up to the present been found only in damp situations, such as moss, dead leaves, etc. There are only three British species, which by some authors have been included with the *Cimicidæ*.

Cimicidæ.

Body very flat. Hemelytra and wings practically absent. No ocelli.

This family contains only about a dozen species, most of which are widely distributed.

They are small, reddish-brown insects, round in shape and very flat. The head is short and broad, with four-jointed antennæ and somewhat prominent compound eyes; there are no ocelli. The rostrum rests in a groove beneath the head. The prothorax is well developed. The legs are moderately long, with three-jointed tarsi. The hemelytra are very rudimentary and wings are absent, so that the broad, flat abdomen is left uncovered.

All the members of this family are parasitic on the bodies of mammals and birds. The ill-famed bed-bug (*Cimex lectularius*) belongs to this family, and is often found in the habitations of man. The life-history has been worked out. Oblong, sculptured eggs are laid in cracks of furniture, flooring, etc.; they are provided at one end with a lid for the emergence of the nymphs, which takes place in from five to ten days after the laying of the eggs. Five moults are undergone before maturity is reached, and in favourable conditions are effected in two months; but the life-history can be greatly prolonged should the conditions be unfavourable. During cold weather the bugs become torpid, laying up in cracks, etc. Before each moult, and before the process of egg-laying, a meal of blood seems to be required. When the bug wishes to suck blood, it injects saliva into the wound made by its piercing organ, causing a flow of blood to the spot, enabling the bug to gorge itself unhindered. Bed-bugs are nocturnal, hiding away in cracks and crannies during the day. They are possessed of an offensive smell. Cockroaches and Red Ants are the best-known natural checks on these noisome insects.

Other members of the family infest birds and bats, and in general characters are similar to the bed-bug.

Four species are found in Britain, of which the notorious *C. lectularius* is the best known.

Beside the mere fact of their unpleasantness, bed-bugs are

regarded with great suspicion, as they might well be the carriers of some dread disease ; but so far no definite accusation can be made, except in India, where it is stated that these bugs aid in the transmission of "kala-azar."

Anthocoridæ.

Hemelytra with embolium and cuneus. Ocelli present. Head produced in front. Third and fourth joints of antennæ not twice as long as first and second together.

This family comprises some 300 small insects of wide distribution. They are usually dull coloured and inconspicuous.

The head is produced to a point in front. Ocelli are present and the eyes are set not far from the pronotum. The antennæ are of moderate length. The hemelytra have both cuneus and embolium ; in a few cases they are somewhat abbreviated, the membranous part being absent. The legs are of moderate length. Some species live under bark, others occur in ants' nests ; the majority are found on flowers, where it is considered they feed on pollen. A few species are definitely known to capture and suck Thrips.

There are twenty-nine British species.

Polyctenidæ.

Hemelytra short, undivided. Antennæ four-jointed. Rostrum three-jointed. Body hairy. Tarsi four-jointed.

Only seven species are known of this curious family. Beyond the fact of their being found on the bodies of certain bats, little is known about them. One species, *Polyctenes lyræ*, has been described as being elongate and flattened, with the head divided into two portions, and the upper surface of the body clothed with minute hairs. Westwood figures *P. fumarius* with the intermediate and posterior pairs of legs very long.

No species have been recorded from Britain.

Capsidæ (*Miridæ*).

Hemelytra with cuneus, no embolium.

This family is one of the largest and most widely distributed of the Hemiptera.

Capsids are small to moderate sized insects, with rather more delicate integument than most of the other families. Bright coloured species are not often seen, the majority being dull yellow, green, brown, etc. They vary in shape, some being narrow and elongate, while others are of more oval form.

Fig. 68.—A Capsid.

The head is distinct, with four-jointed antennæ, of which the basal joint is in many cases dilated. The eyes are well developed and ocelli are present in some species. The rostrum is four-jointed and more or less closely applied to the prosternum, but not in a groove. The hemelytra and wings are somewhat large. The embolium is in some species partially present, but in no case is it entirely so. The legs are slender and moderately long. Capsids fly readily, are active, and many

have the power of leaping like the Halticids. The species of one genus, *Helopeltis*, have a curious structure resembling a pin, projecting up from the scutellum.

The majority of Capsids are herbivorous, occurring in grass and low vegetation. A few species are thought to be predaceous.

Eggs are laid in plant tissues, the female being provided with an extrusible ovipositor for this purpose. In some cases the eggs are provided with a converging long and short process, the ends of which are exposed and not buried in the plant tissues with the rest of the egg. The nymphs usually undergo five moults.

There are 176 British species.

A considerable number of Capsids are of economic importance, as they are injurious to various crops. Species of *Calocoris* are injurious to hops, millet and beet. Two species of *Disphinctus* are injurious to the betel-vine and cinchona. *Dicyphus* spp. attack tobacco. *Helopeltis theivora* is the "mosquito blight" of tea in India. *Heterocordylus* contains species which attack plum and apple trees. Several species of *Lygus* are injurious. *Oncognathus* and *Orthotylus* also contain injurious species. *Plesiocoris* sp. is a pest of apples. *Pœcilocapsus* sp. attacks potato and gooseberry.

(*b*) CRYPTOCERATA

Mainly aquatic. Antennæ concealed. Front of head touching fore-coxæ.

Pelogonidæ (*Galgulidæ*).

Body short and broad. Head very broad, with prominent eyes; ocelli present. Posterior legs thin, formed for running.

A small family of about twenty species widely distributed over the world.

They are small to moderate sized insects, broad and flat in shape and dull of colour. The head is very broad, with the eyes large and prominent: ocelli are also present; the body

as a whole is short, broad and compact. The posterior legs are somewhat long and formed for running. The fore-legs of some species are raptorial and have the femora dilated.

Pelogonids are only semi-aquatic in habit, and are usually found on damp mud, etc., near streams. On land they are very active, running and leaping readily; but in the water their movements are awkward, as they are obviously not adapted for swimming. The life-history is not known; in all probability they are predaceous.

There are no British species, the nearest representative of the family occurring in the south of Europe.

Nepidæ.

Water scorpions.

Fore-legs raptorial, attached to front of prosternum. Abdomen terminated in a pair of respiratory processes.

This is a family of curious insects found in fresh water. They are widely distributed. Recognition should be easy, for they are all flat dingy insects, with large raptorial fore-legs. In shape they are either elongate-oval (*Nepa*), or elongate and narrow (*Ranatra*). The rostrum is short and powerful and the eyes well developed. The pronotum is well developed. The hemelytra entirely cover the abdomen and wings. At the apex of the abdomen there are two long filament-like processes, which, fitting together, form a tube for the passage of the air to the spiracles under the hemelytra. In many cases the dorsal surface of the abdomen, seen only when the hemelytra and wings are apart, is brightly coloured. The intermediate and posterior legs are of moderate length. These curious insects live in shallow, fresh water, preferring that which is nearly stagnant.

The eggs are curious, being provided at one end with a number of filaments, of which there are two in the genus *Ranatra*, and seven in *Nepa*. It is supposed that a supply of air is conveyed to the body of the egg by these filaments. The eggs of *Nepa* are laid in the stems of submerged plants, with the ends of the filaments projecting. *Ranatra* eggs are more usually laid in the stems and leaves of floating plants.

Both nymphs and adults are predaceous, catching and sucking the small forms of aquatic life. They are somewhat sluggish, clinging to weeds, etc., for long periods.

There are two British species, one belonging to *Nepa*, and the other to *Ranatra*.

Naucoridæ.

Posterior tibiæ spiny. Fore-legs inserted on disc of anterior margin of prosternum.

A small but widely distributed family of aquatic insects of moderate size and compact build, usually dull brown or black in colour.

The head is somewhat sunk into the thorax; the eyes are well developed. The fore-legs are more or less raptorial; the middle and posterior legs are formed for swimming, the posterior pair having the tibiæ spiny. The hemelytra cover the abdomen and probably hold a supply of air.

Beyond the fact of their being predaceous and living in fresh water, little is known of the Naucorids. They are much more active than the Nepids.

There are two British species, of which one, belonging to the genus *Naucoris*, is quite common.

Belostomidæ.

Posterior tibiæ flat, with swimming hairs. Antennæ four-jointed. Fore-legs inserted on disc of anterior margin of prosternum.

This family, which contains the largest of the Hemipterous insects, is widely distributed, but chiefly occurs in tropical regions. The species of the genus *Belostoma* are very big, one at least being from 4 to $4\frac{1}{2}$ inches long. There are other species of more moderate size. All are dark brown or black. In shape they are elongate-oval and somewhat flattened.

The head is set deeply in the thorax. The eyes are large and prominent. The rostrum is short but powerful. The four-jointed antennæ are usually hidden, and in the case of *Belostoma*, are received into a very deep, ear-like pocket. The

fore-legs are stout and more or less raptorial; the middle and posterior pairs are formed for swimming. On the abdomen there are short appendages which convey air to a band of pubescence passing laterally round the lower part of the abdomen.

The eggs of some species are carried on the back of the male. The eggs of *Belostoma indica*, one of the largest species, are laid in clusters on plant-stems. In cases where they are known the nymphs are said to more or less resemble the adults. Both nymphs and adults are predaceous, the big species of *Belostoma* not hesitating to attack, and suck dry, a toad. The puncture made by the rostrum of these big species is considered to be poisonous. Some species are attracted by light.

Notonectidæ.

Head concealed below pronotum. Fore-legs attached to posterior margin of prosternum. Rostrum free, three- or four-jointed.

This family, which is closely allied to the *Corixidæ*, is fairly widely distributed.

Notonectids range from quite small to moderate sized forms. They are not brightly coloured, but are usually yellowish or grey. The body is convex and oval. The head is sunk into the thorax; the eyes are large. The rostrum is three- or four-jointed and somewhat stout. The fore-legs, though not exactly raptorial, are used more for grasping than swimming. The air supply is retained under the elytra, and by an arrangement of hairs on the body. Notonectids always swim on their backs, using the posterior legs much in the fashion of oars. They are very buoyant, and when motionless, have to cling to weeds, to keep themselves from rising to the surface. They occur in ponds and tanks, and are probably predaceous.

The eggs are generally laid in the tissues of plants; in some forms they are laid under leaves. The nymphs of some species undergo five or six moults.

Observations have been made on this family by Régimbart (1874), Miall (1895), and Delcourt (1909).

There are two British species, one belonging to the genus *Notonecta*, and the other to *Plea*.

Corixidæ.

Head not concealed. Prosternum short, fore-legs attached to the posterior margin. Rostrum concealed, apparently one-jointed.

This family, the species of which are very like the Notonectids, is of moderately wide distribution.

Corixids are generally flatter in form than the Notonectids, from which they may easily be distinguished in their habitat, by the fact of their swimming in a normal manner, and not on the back. They are usually dark blackish-brown in colour.

The head is free and not covered by the pronotum; the rostrum, which is apparently one-jointed, is generally concealed by being retracted. These insects are much less buoyant than the Notonectids, and are able to remain under the surface without effort: only coming up for air. The air supply is taken directly into the spiracles and not carried in reserve under the hemelytra. They are found in much the same situations as the preceding family, and may often be seen in large numbers resting on the mud at the bottom of ponds.

The eggs are usually glued in masses to submerged objects. In Mexico the eggs of two species are used as food by the natives, as are also the insects themselves. The adults can produce a noise under water by rubbing the fore-legs against the proboscis.

Miall (1895) has made some observations on this family. There are thirty British species, most of them belonging to the genus *Corixa*.

Sub-Order II. *HOMOPTERA*

Hemelytra not thickened at the base. Front of head touching fore-coxæ. Tarsi, with three-, two- or one-joint.

In this sub-order we include also the four families sometimes separated as *Phytophthires* on account of their longer antennæ and more degenerate (parasitic) structure. It is difficult to draw any line between the nymphs of Membracids or Cercopids and Psyllids.

Cicadidæ.

Ocelli in a triangle on the vertex. Antennæ with basal segment and three-jointed bristle.

This family contains the largest insects of the *Homoptera*. About 800 species are known, the majority occurring in the warmer parts of the earth. They are robust insects; some with a wing-expanse of several inches. Colour varies: in some forms the wings are clear and shining, in others both wings and body are brightly pigmented. In many there is cryptic bark colouring when at rest and bright "deceptive" colouring when in flight.

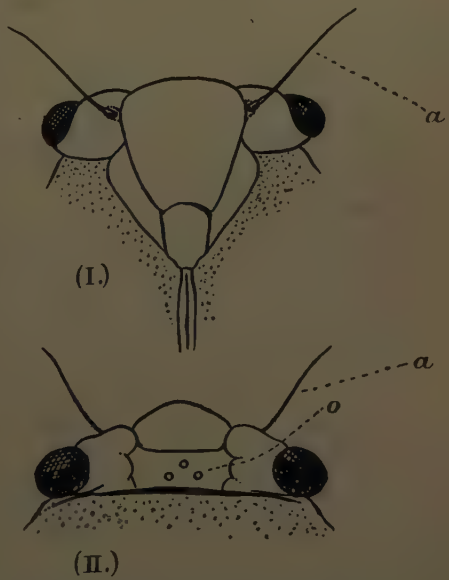


Fig. 69.—Head of *Cicada*. (I) Ventral view. (II) Dorsal view.
a = antenna. *o* = ocelli.

The head is broad and well developed, with small antennæ, consisting of a basal segment furnished with a bristle. The eyes are usually prominent; three ocelli are placed in a triangular fashion on the vertex of the head. The thorax is well developed, with a conspicuous mesonotum. The abdomen is broadly joined to the thorax. At the base of the abdomen in the male are sound-producing organs, with external flap-like structures. The wings are conspicuously veined, and sloped at an angle over the abdomen. The legs are of more or less normal character.

The earlier stages are passed underground, the nymphs living sometimes at a considerable distance from the surface,

and feeding on the roots of trees and plants. When fully grown, the nymph climbs up to the top of the burrow and on to a plant, to which it clings while the skin splits dorsally down the middle of the thoracic segments and the adult insect emerges. The eggs in some cases are laid in bark, the nymphs burrowing into the ground on hatching. The length of the nymphal stage varies, and in one notorious instance is sixteen years, the adult emerging in the summer of the seventeenth year for a short period. The nymphs are very unlike the adults, being colourless and with weak integument; they possess larger antennæ and fossorial fore-legs. The pupæ are shorter in form and have a more shell-like integument; wing-lobes are visible at the sides of the abdomen; the fore-legs are very powerful.

Fig. 70.—Cicadid nymph. (× 1½.)

The adults are most abundant in forests, particularly in moist areas. They feed on the sap of trees. Their presence is made known by the continuous shrill noise made by the males, who produce the sound for no apparent reason, unless it be to attract the females. The sound is produced by the vibration of a tense membrane in the base of the thorax; muscular actions vibrate this membrane and the sound produced is magnified by other membranes and the flap, or operculum, covering the base of the abdomen.

Cicadas are much preyed upon by birds, mantids, etc.

The sub-family *Cicadinæ* is monographed by Distant in the *Genera Insectorum*, Fasc. 142 (1912), and the sub-family *Gœaninæ* in Fasc. 158 (1914). Observations on the seventeen-year Cicada have been made by Riley (1885).

There is only one British species, occurring as a rarity in the New Forest.

The seventeen-year Cicada (*Cicada septemdecim*) is a serious pest in the United States.

Fulgoridæ.

Two (rarely three) ocelli beneath or near the eyes. Antennæ of two joints and a bristle, inserted below the eyes.

This is a family of wide distribution and a large number of species, showing much diversity of form. Some Fulgorids are quite small, others are very large: the Lantern-flies are included in this family; they were so called because the front of the head, extending into a bladder-like structure, was believed to be luminous. Many species are brightly coloured, and moth-like in form; others are quite dull and inconspicuous. With such great variety of form it is difficult to give any definite characters. The head is distinct, and often prolonged forwards and upwards into curious shapes. The eyes of many species are large. Ocelli, usually two, rarely three, in number, are placed in hollows near or beneath the eyes. The antennæ usually consists of two joints and a bristle; the two joints are sometimes prolonged and flattened. The body as a whole is short, but well developed. Hemelytra are present, and wings also, in most cases. The wings are seldom coloured, but the hemelytra are often brightly pigmented; when at rest they slope over the body at an angle. The legs vary greatly; the fore-legs are sometimes expanded leaf-like, while the posterior legs bear tufts of spurs and rows of spines. Some species carry, at the end of the abdomen, tufts or patches of a white, waxy secretion. The female is provided with an ovipositor.

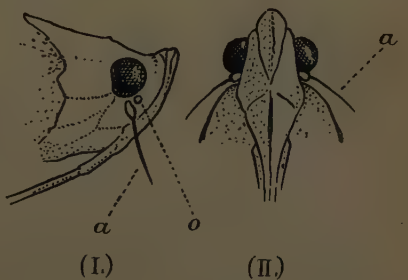


Fig. 71.—Head of Fulgorid. (I) Lateral view. (II) Ventral view.

a = antennæ beneath the eyes. *o* = ocella beneath or near the eyes.

As far as known eggs are laid in plant-tissues, sometimes in bark, and are often covered and mixed with a cottony, waxy

secretion produced by the female. The number of moults is usually five. Some nymphs, especially those of the above-named species, carry long tufts of white, waxy material at the end of the abdomen.

Fig. 72.—Nymph of a Fulgorid last instar (× 4) (*Pyrilla aberrans*).

All, as far as known, are feeders on plant-sap, and are found on trees, plants and in grass. Some species live in the soil on the roots of plants and grass. A few forms are somewhat gregarious.

There are many insect checks on Fulgorids: these include earwigs, Chrysopids, Coccinellids, Dryinids, *Strepsiptera*, Pipunculids. There are about eighty British Fulgorids. Some species are of economic importance, chiefly as pests of sugar-cane; they are included in the following genera: *Delphax*, *Peregrinus*, *Perkinsiella* and *Pyrilla*. A species of *Siphanta* attacks mango in Hawaii.

Membracidæ.

Thorn insects.

Tarsi three-jointed. Prothorax produced backwards into a process. Ocelli placed between the eyes. Antennæ in front of the eyes.

A large family, occurring chiefly in tropical regions.

Membracids are very curious insects of various grotesque forms. They are not large, few being more than 10 mm. in length. The colouring is usually dull brown, which together with their thorn-like appearance render them very inconspicuous.

The head is small and usually concealed by the enlarged prothorax. Two ocelli are placed between the eyes. The

prothorax is produced posteriorly and laterally into a paired or single thorn-like structure which varies greatly in length and shape. The hemelytra and wings are sometimes small; they are folded at an angle over the abdomen when at rest. Veins are distinct. The legs are short, but well developed. The sexes are outwardly similar. In one genus, *Darthula*, the abdomen is produced posteriorly into a bristly process.

Eggs are laid in slits made by the female in the bark of twigs. Sometimes they are very neatly arranged. They are cylindrical, with rounded ends, and have a spine-like process curving from one end. The nymphs are in many cases gregarious, sitting about in clusters on the food-plant. They are quite unlike the adults, there being little sign of the enlarged prothorax.

Both nymphs and adults feed on the sap of twigs, but only of a certain number of plants. In some species the nymphs have an extensile process at the end of the abdomen which excretes a sweet fluid sought by certain species of ants.

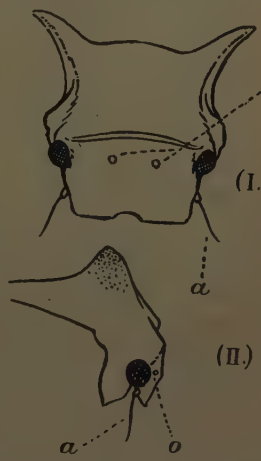


FIG. 73.—Head and prothorax of a Membracid. (I) Front view. (II) Lateral view.

o = ocelli. *a* = antenna.

The group is essentially tropical, with two British species: a few are mentioned as pests in the United States; but generally the group is not economically important.

CERCOPIDÆ.

Frog-hoppers.

Two ocelli on the vertex. Antennæ between the eyes. Hind tibia with stout teeth and a cluster of spines at apex.

This family is widely distributed in both temperate and tropical regions. Its members are small and usually dull-coloured insects; there are large tropical species with warning

coloration. Cercopids are easily distinguished from the Membracids by the simple prothorax, and from the Jassids by the hind tibia being furnished with a cluster of teeth at the apex. They have a curious wedge-shaped appearance. In the sub-family *Machærotinæ*, the scutellum is produced into a spine. Eggs in one instance are laid on twigs. The nymphs of many species live concealed in masses of frothy matter produced by themselves from a mixture of liquid excrement and waxy secretion. These white masses are commonly called

FIG. 74.—Head and Leg of a Cercopid. *o* = two ocelli. *a* = antenna.

FIG. 75.—*Tricophora vulnerata*. (× 6.)

"cuckoo-spit" or "frog-spit." Other nymphs live in tubes formed of a liquid secretion which hardens. In other species the nymphs lead free lives. The adults are very active, many being able to leap a considerable distance. They are usually found on trees, low vegetation and grasses. Natural enemies include egg parasites; the nymphs and adults are eaten by numerous other insects, as well as by toads, birds, and lizards; Williams (1921) records a fungus in Trinidad.

Lallemand monographs the family in *Genera Insectorum*, Fasc. 143 (1912). Seven species occur in Britain.

Jassidæ.

Leaf-hoppers.

Two ocelli on the vertex. Hind tibia with two rows of spines.

A large family of wide distribution.

Jassids are all small, some being quite minute. They are easily distinguished from the Cercopids by having two rows of spines on the hind tibia. In many cases they have delicate integument and are pale in colour, often being green, yellow, or brown; a few tropical species are warningly coloured, others are black. The body as a whole is narrow, with parallel sides. The head is broad, with small thread-like antennæ and two ocelli placed on the vertex; the eyes are not very prominent. The wings are somewhat tightly pressed to the abdomen. The legs are well developed. The female has a concealed ovipositor.

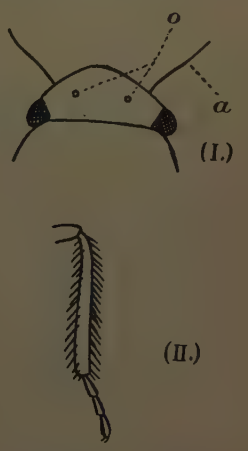


Fig. 76.—A Jassid. (I) Head. (II) Leg. *a* = antenna. *o* = ocelli.

Eggs are laid in the leaves and stems of plants. The nymphs are active, running openly on the plant. The life-history is in some cases very short, several broods being gone through in a year.

Jassids are found almost everywhere: on trees, plants of all kinds, and many grasses. They are very active and have the power of leaping.

There are over 200 British Jassids.

Many species of Jassids are serious pests, either by injuring the foliage of plants direct or by transmitting plant diseases. The more important species are contained in the following genera: *Chlorita* on various crops; *Cicadula* attacks cereals, as does *Deltocephalus*. *Empoasca* is injurious to several crops, and *Eupteryx* to potato. *Eutettix tenella* is the Beet Leaf Hopper. *Idiocerus* is a pest of mango. *Jassus* is

found on various crops. *Selenophorus* attacks rice, and *Tettigonia* apple. *Typhlocyba* is chiefly injurious to the vine.

Psyllidæ (*Chermidæ*).

Jumping Plant-lice.

Small insects. Tarsi two-jointed. Three ocelli; antennæ nine- to ten-jointed; wings, one or two pairs in both sexes, with veins, and sloped over the body. Nymph flattened, partially active in all stages; anal aperture on the ventral surface, with glandular pores secreting wax.

These small insects are common and well distributed in temperate and in tropical regions, being found both on plants and in galls formed by them on plants; the scheme of coloration is usually cryptic.

The antennæ are moderately long; the head is well developed in the adult, that of the nymph much less so; the head is provided with a sucking beak and compound eyes. The abdomen is well developed, and the legs are formed for running, the hind pair for leaping. The thorax has one or two pairs of hyaline wings, with usually five veins. Though the males and females are similar in general appearance, the males can easily be distinguished by the fact that their genitalia are turned upwards and curved; those of the females are straight, pointed, and concealed between the upper and lower segments of the abdomen. In addition, the abdomen of the fertilized females is slightly broader than that of the males. The spiracles in the adult lead directly to the main tracheal trunk; in the larva there are various protective devices, between the external opening and the tracheal trunk, which are as follows:

"(*i*) *The Spiracles* (three on the abdomen, and two on the thorax) are each situated in a pit which is covered with long hairs.

"(*ii*) *The external lid of the spiracle.* This is formed by a thick process which lies across the spiracle.

"(*iii*) *The closing apparatus.* This consists of thickened chitin stretching from one side of the tube to the other. It is acted upon by the spiracular muscles which are attached to

this apparatus. When these muscles contract, this transverse bar of chitin is pulled apart and the spiracle is opened.

"(*iv*) *Atrium*. Below the closing apparatus is a cavity which communicates with the main tracheal trunk.

"The simple structure of the spiracle of the adult and the more complex structure of that of the young lead one to infer that the adult will react more readily to an insecticide, and this is actually the case." (Awati, 1915.)

The females have nine or ten egg-tubes on either side, which communicate with two oviducts, and open into them; the oviducts themselves join and open into the vagina ventrally, as one duct. The vagina has powerful circular muscles

FIG. 77.—Indigo *Psylla* ♀ (× 20) (*Poyllopa punctopennis*). Hind-end of abdomen of ♂. (× 20.)

and accessory glands: the latter open into the distal portion. The spermatheca lies below the vagina and oviducts, and also has an opening into the distal portion of the vagina, which itself communicates with the ovipositor; the ovipositor is formed by the invagination of the posterior segments of the abdomen.

The eggs are, in the majority of cases, laid singly and unevenly; this is certainly the case with *Psylla mali*, the apple sucker (Awati, 1915), and with the Indigo Psylla (Lefroy, 1913). Marlatt states that in the case of *Psylla pyricola*, the pear-tree Psylla, in Maryland, U.S.A., the eggs are placed singly, in rows, or in bunches, in crevices of the bark or twigs.

The egg of *P. mali* is oblong, tapering at both ends and sculptured; as the time for it to hatch approaches, it becomes reddish instead of pale white. There is a long free-hanging stalk present at one end and a short arm-like sucker, which fixes the egg down. The spot where the young nymph, or larva, emerges is best compared with the "dovetailing" which is practised by carpenters. This "dovetailing," coupled with the egg-breaker on the fore part of the head of the nymph, renders the emergence from the egg easy; it is further facilitated by a number of dorsal and ventral spines which serve to keep the sides of the egg apart. The larvæ or nymphs are flattened; there are five instars, the sixth being the adult stage; the wing-lobes develop in the third, fourth and fifth instars. The nymphs produce an opaque white secretion in the form of a thread, hanging from the posterior region of the abdomen; it is the heart-shaped organ which produces this thread: the thread is of a waxy nature and readily soluble in alcohol. The thread acts as a duct to convey away the translucent liquid excreta, ensuring that it shall not wet the leaf in too close proximity to the nymph; some Psyllids produce a "honey dew." The spine-like threads of wax are produced from the extremity of the abdomen (Awati, 1915).

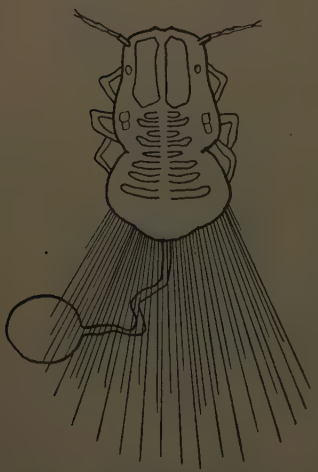


FIG. 78.—*Psylla mali* Nymph and its Secretion.
(After Awati.)

The food is cell-sap, and Psyllids can cause most serious damage to plants, most of the damage being effected by the nymphs, which are gregarious; the adults themselves cause but little real damage to the plant. *P. mali*, in England, hibernates in the egg stage. Awati states that the duration of the first, second, and third instars is from seven to eight days, the fourth from ten to fifteen days, and the fifth from twelve to fourteen days; this places the period from the egg to the perfect insect at from forty-three to fifty-three days. Egg-

laying extends over a period of about a week ; the females live some time after it has taken place, the males dying before the females. *P. pyricola* has three broods in England, four in America, and hibernates as an adult. Psyllids frequent a great variety of plants, many of them forming galls. *Psylla buxi* forms a small gall, rather resembling a miniature cabbage, on the apical shoots of the Box, while *Psyllopsis fraxini* causes galls on the leaves of the common Ash. Psyllids usually seem to prefer the under sides of the leaves on which they are found. Awati states that in the larval condition *P. mali* is positively thigmotropic, i.e. it reacts positively to pressure, and so tends to collect between the closely packed leaves and inside buds ;

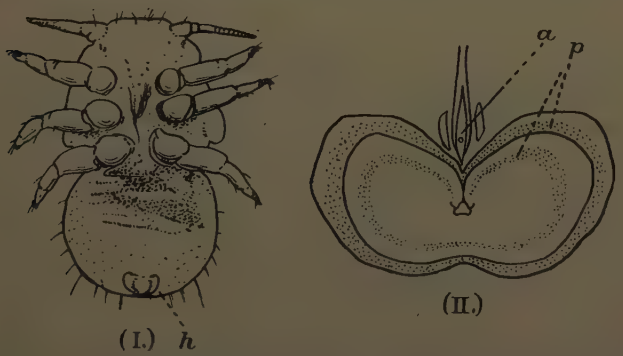


FIG. 79.—(I) *Psylla mali* (× 30) Nymph, ventral view, to show the heart-shaped organ. (II) Heart-shaped organ more highly magnified.

h = heart-shaped organ. *p* = wax pores. *a* = aperture leading to outside.

this, combined with negative heliotropism, ensures that they shall feed on the tenderest portions of the plant. At the fifth, or last instar, they become negatively thigmotropic, and live freely in the open, losing the gregarious habit which they possessed in the first four stages after hatching.

Psyllids have a number of enemies, chief among which are the *Coccinellidæ*, *Chrysopidæ* and *Syrphidæ*. Awati mentions a predaceous mite which he states is the only enemy of *P. mali* in England, of any importance. When, however, Psyllids are very abundant, spiders and mantids account for a considerable number.

Psyllids are widespread, as abundant in the tropics as in

the temperate regions. The fifty-seven British species are described in Edwards' *British Homoptera* (1896); Crawford (1914) monographed those of the New World; Witlaczil (1885), Loew (1876, 1878), Patch (1909), have written on the group. Crawford (1914) makes six sub-families and gives a bibliography. The economically important species include the Apple Sucker of Europe, the Pear Suckers of Europe and America, *Psyllopa punctipennis* on indigo in India, and *Euphyllura oleæ* on the olive in South Europe. The usual remedy is spraying the nymphs, and in some cases winter washing with a lime wash to destroy the eggs.

Aphidæ.

Plant-lice, Greenfly.

Small, often wingless; tarsi two-jointed. Antennæ three- to seven-jointed. Abdomen usually with a pair of siphons. Wings, when present, hyaline and with few veins; the fore-wings larger than the hind-wings.

These insects are common and extremely numerous, both in temperate and in tropical regions. They are usually of such dull colours as black, brown, yellow, and the more sombre greens. Some are mealy, whilst others are more or less thickly covered with waxy threads. In size they are rarely longer than one-tenth of an inch.

The head is distinct, the antennæ being long and straight and consisting of from three to seven joints. Sharp, however, says that "it is doubtful whether the antennæ have ever really more than six joints, the apparent seventh joint being actually a sort of appendage of the sixth." The eyes are more often small and compound; there is frequently present a curious supplementary eye, or tubercle, on the cornea of each compound eye. Each tubercle has from five to ten hemispherical lenses, very similar to those of the compound eyes. These tubercles are found in the winged forms in addition to ocelli. In some aphids the eyes are rudimentary or entirely absent. Ocelli are never found in the nymphal stages, but there are always three, or rarely six, present in the males and in the winged

females. The rostrum is, externally, three-jointed, and varies greatly in length; the rostrum, haustellum, or proboscis, in *Stomaphis* is nearly twice the length of the thorax and abdomen combined. The youngest nymphal stages of Aphids frequently have the rostrum as long as the abdomen and thorax, those of *Eriosoma* having the rostrum a little longer than this. The rostrum itself can be retracted, like a telescope, into the head, up to two-thirds of its length: this sets free an additional length of stylets, or setæ, for insertion into the tissues of the

FIG. 80.—*Phorodon Humuli* Apterous viviparous ♀.
c = cornicles.

plant. Buckton (1878) places the number of stylets at three; however, it has now been shown by Grove (1909) and Davidson (1913) that there are four present, representing the mandibles and maxillæ. The thorax is distinct and fairly well chitinized in the winged forms; in the nymphs and wingless forms the thorax is not very evident, the general outline of the insect not deviating appreciably as one passes from the head to the initial segments of the abdomen. In the abdomen, nine visible segments are usually recognized, but this is a much

disputed point, Balbiani (1869) considering ten to be present in addition to the cauda. The cauda, or tail, is not always present; it is formed by the prolongation of the last segment, beneath which is the anus. Situated on the dorsal surface of the fifth abdominal segment is a pair of processes known as the cornicles; they are also called nectaries, honey-tubes, siphuncles and siphons by various authors. They are glandular, globules of waxy matter being secreted. The cornicles do not produce honey-dew as is frequently stated; the honey-dew is an anal secretion and is much favoured by ants as food.

The sex of Aphids can only be determined with certainty by dissection; in general, when the abdominal region is comparatively small, it may be taken as an indication of the male sex, since the testes are much smaller than the egg-tubes of the female. The males are often very small, but are sometimes provided with large wings; they may be either winged or wingless, but are usually the former. The wings of the males have a venation similar to that of the females. The males appear several days before the females. The mouth-parts in the male are well developed.

The winged and wingless viviparous females are by far the commonest, and are determined easily by dissection. Externally, they are of a more robust appearance than the males, the abdomen being much swollen. The oviparous females are wingless in the sub-family *Aphidinæ*, but may, or may not, possess wings in the remaining groups. These oviparous females are usually smaller than the viviparous females, and have robust bodies and stout limbs; the tibiæ may bear plate-like expansions; the antennæ, though seldom lacking the full number of joints, are often shorter than those of the viviparous females.

The internal anatomy has been worked out in but few types. Witlaczil worked on *Aphis* in 1882, and this was followed, in 1884, by a study of the development. *Trama* was investigated by Mordwilko in 1895, while Dreyfus has studied the anatomy of *Phylloxera*. Of the more recent morphological work, Grove (1909) has worked on *Macrosiphum* (*Siphonophora*), *rosarum*, and Davidson (1913) on *Eriosoma* (*Schizoneura*) *lanigerum*. A brief account of the two latter studies is perhaps the best method of conveying an idea of the internal anatomy

of Aphids. In *Eriosoma*, wax glands are present in transverse rows near the posterior borders of the thoracic and first seven abdominal segments, four in each segment ; there are also two on the eighth abdominal segment, and ten on the epicranial region of the head. Each, externally, consists of several polygonal areas surrounding a facette, beneath which is situated a number of large gland-cells. Each facette is provided with a glandular cell which produces the waxy secretion ; at the base of each cell lies the lumen into which this secretion is poured ; it passes through the chitin of the polygonal areas in the form of fine waxy threads. Sharp (1918) suggests that the wax glands may replace the cornicles to some extent.

The mouth leads into the pharynx, which is lined with thickened chitin on the posterior and ventral walls, the anterior wall being of flexible chitin. A number of muscles are attached to this flexible anterior wall and are capable of drawing it outwards, thus enlarging the pharynx considerably and causing the cell-sap of the plant to mount up the anterior duct of the stylets ; the capillarity of this duct probably assists this operation considerably. The relaxation of the muscles closes the opening to the pharynx. The sap is thus prevented from flowing back into the mouth and is forced into the œsophagus. The œsophagus is invaginated into the stomach, forming an œsophageal valve which ensures that the sap, once it is in the stomach, is not regurgitated. The stomach is formed by the enlargement of the fore-part of the gut, which latter gradually narrows posteriorly and becomes the intestine. The intestine, which is coiled, leads into the rectum. Since the Malpighian tubules do not occur, the rectum is thought to function as an excretory organ (Kowalevsky, 1889). The nervous system is concentrated in the head and thorax, the supra-œsophageal ganglia occupying most of the head. The elongated median ganglian, lying in the thorax beneath the œsophagus, represents the fused elements of the thoracic ganglia. Considering the sluggish nature of Aphids, as compared with other insects, the tracheal system is extraordinarily highly developed, there being nine pairs of spiracles present. The first seven abdominal segments each have a pair, and there is a pair on the prothorax and on the metathorax. The spiracles all communicate with a system of large ventral and dorsal tracheal trunks. While

Witlaczil (1882) found a dorsal vessel, or heart, in *Aphis*, and Mordwilko the same organ in *Trama*, Dreyfus, Grove, and Davidson, working respectively on *Phylloxera*, *Macrosiphum* and *Eriosoma*, all failed to find it. The circulatory system is very poorly developed.

The reproductive system is very simple and occupies much of the body cavity. In the female it consists of a number of egg-tubes in which may be found embryos in various stages of development. The egg-tubes lead into two oviducts, which latter join to form a stout muscular vagina leading to the genital aperture. The embryos, in their earlier stages of development, were called pseudova. Huxley (1858) has described their development in *Aphis*. The number of embryos found at one time in a female varies from twenty to eighty or more. The pseudo-vitellus, which consists of masses of large round cells, is to be found in the posterior half of the abdomen, close to the egg-tubes. Witlaczil (1884) and Will (1888) described its origin and development, and its function is probably concerned with the nutrition of the embryos, though this has not yet been properly established. The fat-body extends beneath the integument, and over the internal organs, being mostly found in the anterior portion of the abdomen and in the thorax; it consists of yellowish-brown masses of cells.

The outstanding feature of the life-history of Aphids is their extraordinary fecundity: this is due, however, not to the number of young produced by each individual, but to the fact that the young commence to reproduce so soon after birth. The life-histories may be exceedingly complicated, and may vary to a great extent. A simple life-cycle runs as follows: Eggs are laid in the autumn and hatch in the spring, giving rise to apterous viviparous females which, eight to twenty days later, produce young parthenogenetically. These first females are known as fundatrices, or stem-mothers, and they are frequently much larger than the ordinary apterous viviparous females. Generations continue to be produced parthenogenetically for some time, and may include amongst them a greater or less number of winged individuals, with perhaps a few males. Finally a sexual generation is produced, which lays fertilized eggs. This cycle may be complicated by migrations from one

food-plant to another and back again; or from root to aerial portion of the plant and back again; or by a combination of these two. It is important that this should be recognized when dealing with Aphids—from the economic standpoint. Aphids may be parthenogenetic or sexual, and either of these may be oviparous or viviparous, winged or wingless; in addition successive generations may differ greatly in their habits, or the individuals of the same generation may so differ; when the individuals which differ are of the same generation, they constitute what is known as a parallel series.

The factor which influences the production of winged or wingless forms was, until quite recently, uncertain; the constitution of the cell-sap of the plant, combined with the temperature, was considered to be the chief influence. Davidson (1921), however, conducted a series of breeding experiments,

Fig. 81.—Wings of *Macrosiphum* sp.

which showed, when they were taken into consideration with cytological investigations, that it is probable that the sequence of winged and wingless forms is largely accounted for by some "internal inherent tendency." Winged viviparous females have a strong tendency to produce apterous viviparous females, whilst apterous viviparous females are very liable to give rise either to apterous viviparous females or a mixed progeny, including a varying percentage of winged forms.

Where the food is seasonable and the temperature conditions are favourable, the apterous condition may be deemed to be the form which is most adaptable. The great variability in the number of the winged forms, produced by apterous individuals, should not be lost sight of in considering this question. Food and temperature are also responsible for the

sexual forms ; later cytological work showing it to be associated, in addition, with changes in the chromosome complex. Agamic generations appear to be interpolated between the winter egg and the sexual generations as an adaptation to seasonable conditions ; sexual generations may, in certain cases, be followed by continued parthenogenetic reproduction, these forms lying dormant through the winter, or only reproducing very slowly ; the next season the rapid reproduction is continued. Clarke (1901) grew rose-cuttings in sand saturated with magnesium salts and infected them with the common rose Aphis. He found that a higher proportion of winged forms was produced than was usual. This has been repeated successfully by Neülls (1912), and by Shinji (1918). Gregory (1917) found that the proportion of winged forms could be raised by starving the parent during its development. Haviland (1921) has experimented further on these lines. According to Buckton (1876), the number of broods in a year is very variable. Some species are thought to have only one, whilst in others the number approaches eighty or ninety.

Aphids are universally plant-feeders, on sap, and the majority of cultivated plants are subject to attack by one species or another ; the economic importance of this group, therefore, is very great. Some species form galls either on the stems, roots, leaves, or petioles ; in some cases the Aphids live externally, whilst in others they are to be found inside the galls which they themselves have caused the plant to create for them. Aphids greatly lower the vitality of their host as they suck out of it a large quantity of sap : in addition, fungal and bacterial diseases often set in secondarily. This secondary attack is of common occurrence where sucking insects are concerned with the original damage. These fungi or bacteria are probably either injected into the plant through the stylets of the insect or gain admittance through the wounds produced by the stylets. In addition, the attack of some species is followed by gall formation of a serious kind ; this is particularly notable in the woolly Aphis of the apple (*Eriosoma lanigera*) and in species of *Pemphigus*.

Checks are Chalcids and other parasites, Coccinellids, Syrphids, Chrysopids, Hemerobiids ; birds eat Aphids, and some Fossorial Hymenoptera lay them up for their larvæ. A Cecidomyiid feeds upon them (Davis, 1916).

The group is an immense one in temperate regions and less so in the tropics. Many species are now nearly cosmopolitan, and there is great confusion in nomenclature. Buckton's monograph (1876–1878) dealt mainly with British species; Theobald, Pergande, Schouteden, Baker, Van der Goot and Mordwilko have described or written up the species; there is a very large economic literature, and we sorely need good monographs and a revised classification and nomenclature.

Baker (1920) has published a generic classification of part of the family: he distinguishes the two sub-families, which he calls families, *Aphidinæ* and *Phylloxerinæ*. The former have only sexual oviparous forms, and the stigma is formed by the radius: the latter has summer parthenogenetic oviparous forms, and the stigma is found by the radial sector. He subdivides the *Aphidinæ* as follows (all his characters are not given here).

Eriosomatinæ. Sexual forms without functional mouth-parts, one egg laid, cornicles reduced or absent, wax glands abundantly developed.

Mindarinæ. Sexual forms with functioning mouth-parts, oviparous female laying several eggs. Sexes small.

Hormaphidinæ. Usually gall makers. Nymph often Aleurodiform.

Aphidinæ. The normal greenfly or free-living Aphids.

The *Aphidinæ* include *Lachnus*, the subterranean *Trama*, *Phyllaphis* on beech, the solitary-living *Callaphis*, and the common "Greenfly" on crops such as *Aphis*, *Rhopalosiphum*, *Macrosiphum*.

Mindarinæ include only one genus on conifers.

Eriosomatinæ are the gall-makers, and include the subterranean *Forda*, which lives in ants' nests.

Hormaphidinæ are notable chiefly for *Cerataphis*, in which the nymph is flat, limbless, black with a white waxy fringe, making it very like an Aleurodid nymph. The student should consult Baker's work for further details of classification.

There are many economic species; these include: (*a*) species living above ground, with a food-plant cycle; (*b*) root species; (*c*) gall-forming, root and above-ground forms, such as *Eriosoma* and *Phylloxera*; (*d*) conifer-feeding forms, such as

Chermes, which have a complicated cycle of sex forms, migrants and food-plants.

The greatest vine pest was *Phylloxera vastatrix*, an American species introduced to Europe; the greatest apple pest is *Eriosoma lanigera*, introduced to England about 1789, and probably itself indigenous to America. Others are major pests on wheat, cotton, hops, mustard, plum, melon, etc. Their control depends upon a study of food plants, natural enemies and climatic influences; and while spraying is largely done, on hops for instance, it is a wasteful and unsatisfactory method.

Aleurodidæ.

White fly, Mealy wings.

Two pairs of wings, sloped over the abdomen; the wings and body covered with mealy wax; the nymph flat, scale-like after the first moult, usually with a waxy fringe. The rectum opens on a dorsal process, which lies under a plate, in the vasiform orifice.

Mealy wings are, in the adult stage, small, white, or black and white, moth-like insects, found on plants. Colour probably has no significance. The white waxy covering is formed of short curled waxy filaments, secreted from unicellular glands and spread over the body, legs and wings, probably as a protection.

The adult has a distinct head, with seven-jointed antennæ, compound eyes, and two ocelli; the mouth-parts are much as in Aphids, with long stylets and a short labium, the stylets not actuated from the head, but by the labium. Spiracles are situated on the mesothorax and on abdominal one and seven. At the dorsal apex of the abdomen is a semicircular orifice, partly covered by a plate, under which lies a process carrying the anal opening. There are glandular areas on the ventral surface of abdominal segments two and three, secreting the waxy filaments. The pseudovitellus is visible inside the abdomen about the second and third segments.

The male has claspers, the female a short ovipositor. As a rule both sexes are present, but *Aleurodes vaporariorum* is frequently parthenogenetic.

The life-history is known in several species: eggs are laid usually on the leaf, often in circles, each egg with an anchor process embedded in the cuticle. The first nymph is active, walks about and finally settles down: its stylets reach the phloem of a vascular bundle. Moults occur, the insect emerging from the anterior end, and settling down again; the legs and antennæ degenerate. The anal orifice is on a process similar to that of the adult, which enables the liquid excreta to be flicked away from the body. The fourth instar

Fig. 82.—*Asterochiton* (*Aleurodes*) *vaporariorum* ♀ (× about 30).

is a pupal one, from which the adult emerges. A feature of all instars after the first is the waxy covering, spines and margin: the last is very noticeable, and in conjunction with the plate on the dorsal anal orifice, readily enables these nymphs to be distinguished from Psyllids and Coccids (see also *Cerataphis*, under Aphids).

The length of the life-history varies with temperature and humidity: in the greenhouse species, it occupies up to 100 days from egg to adult (Hargreaves, 1915); in Louisiana it occupies

from forty to fifty days in summer to six months in winter (Rosenfeld, 1907).

Food-plants may be very varied as in the Greenhouse White Fly, or limited as in the cane and orange species.

Hibernation probably takes place mainly in the adult stage. Natural enemies include Chalcid parasites, Coccinellid beetles,

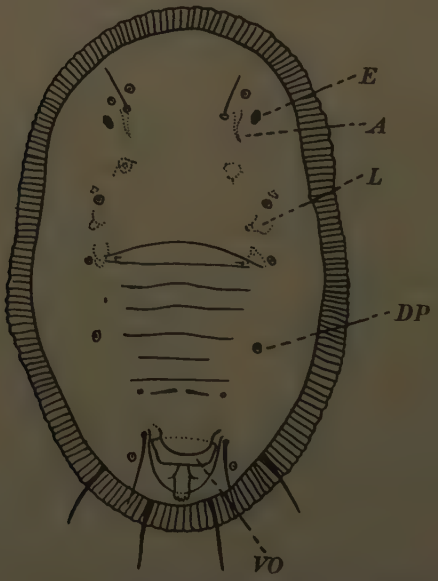


FIG. 83.—Larva of *Asterochiton* (*Aleurodes*) *vaporariorum*, second instar. (× 120, approx.) Ventral structures shown dotted.
E = Eye. *A* = Antenna. *T* = Leg. *DP* = Dorsal pore. *VO* = Vasiform orifice.
(Adapted from Hargreaves.)

Syrphids, Chrysopids, Hemerobiids. Much has been written about fungi, such as *Aschersonia*, *Sphærostilbe*, etc. (Berger, 1909), but it is not certain that these are primary checks on the living nymphs.

The greater number of species are tropical. Four species are common in Britain: the two Brazilian species, *Aleurodes* (*Asterochiton*) *vaporariorum*, the greenhouse species, and *Aleurodes filicium*, on ferns, and *Aleurodes brassicæ*, and *A. proletella*, the garden species found on crucifers. Other species occur on wild and cultivated plants. Kirkaldy's Catalogue (1907) lists 136 species of the world, including thirteen British.

Quaintance has revised the generic nomenclature (1913, 1914) and classification, and has further dealt with the group in *Gen. Ins.* Fasc. 87 (1908).

The family have some economic importance. The Greenhouse White Fly (*A. vaporariorum*) is a very serious pest to tomato and cucumber under glass; several are pests to *Citrus* in the United States; others attack sugar-cane in the East, tobacco,

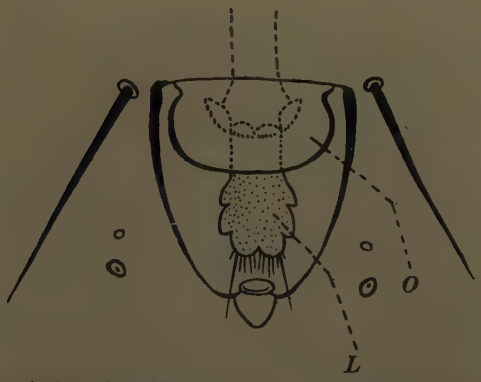


FIG. 84.—Dorsal view of vasiform orifice of larva of *Asterochiton* (*Aleurodes*) *vaporariorum*. (× 300, approx.)
L = Lingula. *O* = Operculum.
(With slight alterations, after Hargreaves.)

crucifers, coco-nut, and other palms. Fumigation with hydrocyanic acid, spraying, the use of natural enemies, are the chief methods used against them.

COCCIDÆ.

Scale insects and Mealy bugs.

Tarsus one-jointed with one claw, female wingless, male with one pair of wings and a metathoracic hooked process engaging with the wing.

The insects of this family are easily recognized in the field, the male by the single pair of wings, the double compound eye, the absence of mouth-parts, and in some the long external penis. They are often extremely small, the body powdered

with wax and usually coloured red or yellow. The females are recognizable either by their fixed habit upon the plant, with the legs and antennæ reduced or absent, or by their comparatively long antennæ, covering of wax and very varied form of ovisac; most are covered with wax in a great variety of form, whilst in one sub-family (*Diaspinæ*) the flat insect is covered with part of two previous moults, added to by a

FIG. 85.—*Orthezia cataphracta*. (× 9.)

felted waxy covering forming the "scale." The colour is varied and has probably no significance.

The structure of male and female is so different that they need to be separately considered. The male has, in addition to the points already mentioned, long antennæ of ten or more joints, a distinct round head with often a second pair of eyes on the lower surface, no mouth-parts. The thorax is distinct, well developed, and bears a pair of functional wings. The hooked process of the metathorax, which engages with the hind edge of the wing, may be the metathoracic wing. The abdomen is long, with distinct segmentation,

usually with a long penis, and often with a pair of long waxy processes projecting backwards.

The adult female has antennæ varying from fully developed functional ones (with six to ten joints) to very reduced or completely reduced non-functional ones. The head, thorax and abdomen usually form a single mass. The legs may be long and functional, or very reduced. The mouth-parts are essentially of the Rhynchotous type, but the stylet formed by maxillæ and mandibles is usually situated in a ventral sac, is extremely long, and it is held by the separate labium, which has a muscular apparatus which forces the stylet into the plant. The labium is short, and the style is not forced into the plant by muscles in the head as in *Heteroptera*. The females commonly have two pairs of thoracic spiracles, but in some large forms (*Monophlebus*) there are also a number of abdominal pairs. A feature of the female Coccids is the variety of anal armature: in *Lecanium* and its allies there are two triangular flaps; in *Dactylopius* an anal ring of setæ; in the *Diaspinæ*, the whole pygidium bears groups of unicellular glands, which secrete threads which are felted into a scale by the aid of a complex series of hairs and spines situated on the posterior margin. These complications of glands and spines are almost the sole method of specific identification in this sub-family. Interesting points in the internal anatomy are the alimentary

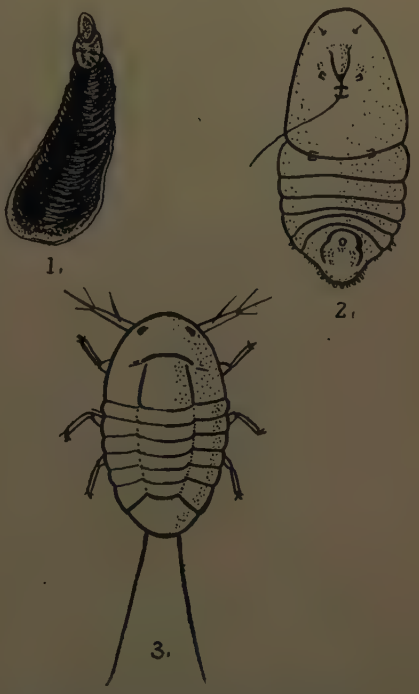


FIG. 86.—*Lepidosaphes pomorum*.
1. ♀ scale (× 10). 2. Adult ♀ (× 30).
3. Larva (× 60).

FIG. 87.—*Pseudococcus citri* ♂.
(After Rhynhardt, with alterations.)

canal of some forms, in which the rectum is coiled round the mid-gut without direct connection, and the ovary, formed of a large sac bearing many small egg-tubes irregularly arranged.

FIG. 88.—Diagram of mouth-parts of *Pseudococcus citri* ♀. (× 150, approx.)
(After Rhynhardt.)

The life-history is known in many cases. Usually eggs are laid, either in an ovisac formed of cottony wax, or under the scale on the body. In some the eggs hatch internally, or immediately on laying. There emerges a flat oval insect, with legs and antennæ, which walks about. It eventually settles down, inserts its stylet and feeds on the liquid it obtains from the plant. In some species, sex is

distinguishable in this stage (Green). As a general rule there is then a divergence of appearance. The male moults twice, and appears as a prepupa, with wing-lobes: it then moults again, appearing with larger wing-lobes. The fourth is the final moult, and the two instars before the imago are immobile and without functional mouth-parts. The female moults twice after the first moult, retaining the habit of feeding, but suffering often a large degree of degeneration in legs, antennæ and eyes; but some species retain the legs, antennæ and eyes (simple).

There is often a marked difference in the number of each sex, and in some species perpetual or partial parthenogenesis is the rule. Newstead records males of *Mytilaspis pomorum* only from certain food-plants, and parthenogenetic females only from others. In *Tachardia* there appear to be two forms of males, winged and wingless, but this requires investigation. The same occurs in *Chionaspis salicis* in Britain (Newstead).

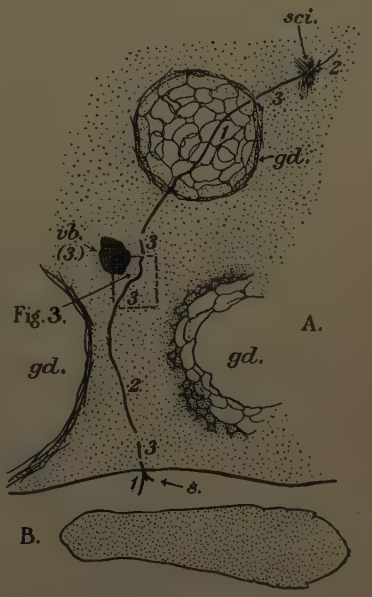


Fig. 3.

Fig. 89.—Stylets of *Lepidosaphes beckii* in rind of orange. A. Transverse sections of portions of rind of orange, with stylets *in situ*. Three sections reduced to one plane (× 90). Numbers to portions of stylets, etc., indicate sections in which they occur. B. Outline of the Coccid (*Lepidosaphes beckii*) on the same scale. Traced with camera lucida from an adult female.

gd = oil gland. *s* = stylets. *vb* = vascular bundle. *sci* = sphere crystal.

(Drawn from sections by L. N. Staniland.)

The number of broods a year varies from one to as many as five or six, depending upon food and climatic conditions. Hibernation takes place as eggs, first instar nymphs or females. In India *Monophlebus* æstivates as an egg, appearing only in the cold season.

The food is entirely derived by suction from plants, and it

has been shown that the stylet reaches tissues comparatively far from the outside.

As a result of infestation, galls are formed in some cases, or malformations of shoots, and one sub-family live inside galls (*Brachyscelinæ*). Most live openly on foliage or bark, some on roots in the soil; some are limited to a few food-plants, others have a wider range.

A sequel to the attacks of Coccids upon plants is the deposition, on the upper surface of the leaves, of the sugary

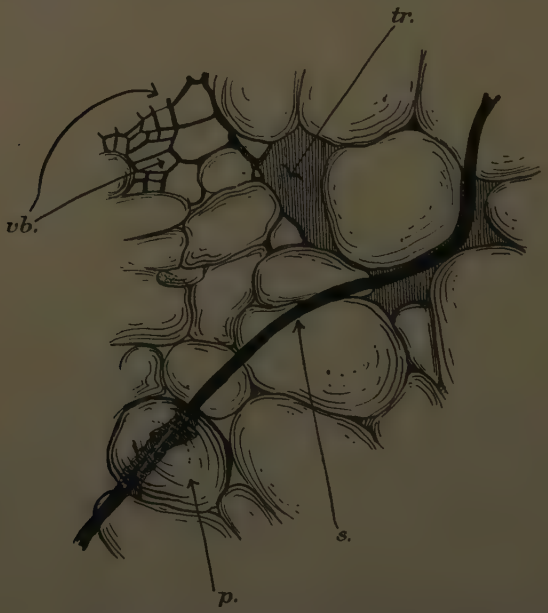


FIG. 90.—Stylets of *Lepidosaphes beckii* in rind of orange. Enlargement of portion of Fig. 89 marked Fig. 3 (× 480).

vb = vascular bundle. *p* = cell pierced by stylets. *s* = stylets. *tr* = salivary tract in intercellular space.

(Section by L. N. Staniland.)

liquid excreta, in which flourish moulds, which form a black covering over the leaf, and which cuts off light and leads to weakness of the plant. This is often a cause of damage in the tropics.

The checks on this group are many. Coccinellids and Hymeropterous parasites comprise the great number. Chrysopids, some Acalyptrates, a Lycænid, some Noctuids and

Tineids also feed upon them. Some birds feed upon them, fungi have been used to destroy them, and there is probably a definite correlation between the vigour of the host-plant and the degree of infestation by the Coccid, the vigorous plant escaping attack to some extent. The family is a very large one, well distributed over the world. The literature is immense.

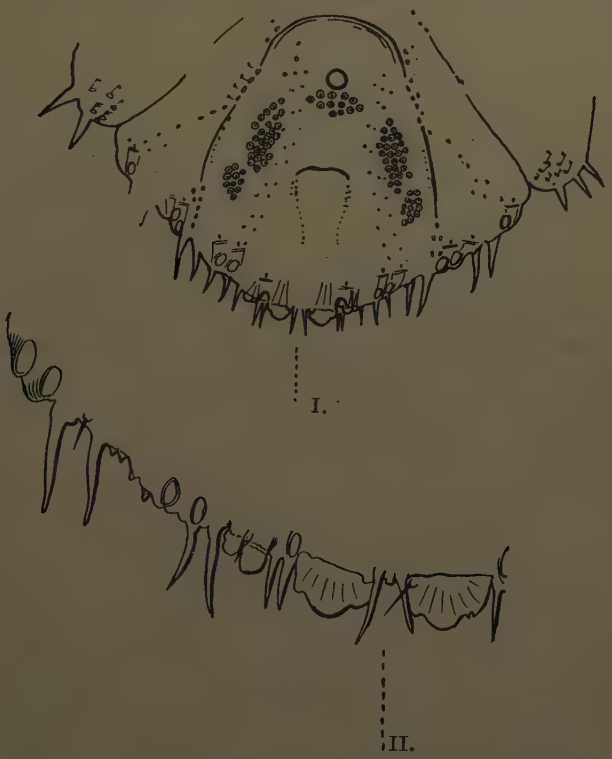


Fig. 91.—Pygidium of *Lepidsosaphes pomorum*. (I) Pygidium of adult ♀ (× 160). (II) Margin of same pygidium (× 400).
(After Newstead—somewhat simplified.)

The classical authorities are: R. W. Newstead (British Coccidæ, etc.), T. D. A. Cockerell (tropical Coccids), E. E. Green (Coccidæ of Ceylon, etc.), the late Mr. Maskell (New Zealand) and Mr. Douglas (England). A catalogue of the family was prepared by Mrs. Fernald (1903) and supplements have been issued by the United States Federal Bureau from

time to time. Signoret wrote a series of papers prior to the above authors, and there is an enormous literature relating to species identification and to their economic importance. Newstead enumerates eighty-eight species in Great Britain, of which forty are indigenous, forty-eight introduced, of which forty-six are found under glass. Of the forty indigenous, eleven are of some economic importance. A number of British species have been since described. The total known species are probably over 2,000.

The economic importance of this family is equal to all other *Rhynchota* together. Such species as the San José Scale, the Peach Scale, the Fluted Scale, the various scales on Citrus, Palms, Coffee, have been of almost world-wide importance. The immense spraying industry of America was built up as a result of the San José Scale. Coffee in Ceylon was destroyed by Green Bug (*Lecanium*) and coffee-leaf disease, and there are species threatening practically every permanent tree crop, such as fruit, rubber, tea, coffee, cacao, palms, vines, mulberry. These species have been carried over the world on plants. It is practically impossible to detect first instar nymphs by inspection, and only fumigation will really clear infested plants.

The Coccids include three groups whose products are useful to man. The most important is lac, the resin-wax emulsion which covers the bodies of the female lac insect. The total value of lac used in the world amounts to several million pounds. Formerly lac was grown or collected for the dye: now the dye is useless, and the resin is used in industry.

The Cochineal insect is also cultivated, mainly as a dye for use in food, but also as a very fast bright dye for silk. It grows upon a prickly pear (*Opuntia*), and its culture is diminishing.

Chinese white wax was derived from *Ceroplastes ceriferus*, being the thick soft covering of this scale: it is no longer an important article of commerce.

The student will find great difficulty in following the literature owing to the periodical shifting of generic names. As generic names change swiftly at the whim of each new author, the student will be well advised to look out for

specific names, and especially for popular names in English words.

The following sub-families are those of Fernald's Catalogue and supplements:

Monophlebinæ. *Monophlebus* includes the species with very large females and males. *Llaveia* (formerly *Coccus*), *Drosicha*, *Monophlebulus*, *Guerinia*, *Palæococcus*, *Walkeriana*, also occur. *Icerya* includes the notorious Fluted Scale, now widely spread. The Cochineal insects come under the old genus *Coccus*.

Margarodinæ. *Margarodes formicarum* in the West Indies forms a pearly covering in the soil.

Ortheziinæ. *Orthezia insignis* is widespread; the active female bears a long erect ovisac. *Phenacoleachiinæ* includes New Zealand species.

Conchaspinæ. *Conchaspis* is the known genus.

Dactylopiinæ. *Asterolecanium*, *Cerococcus*, *Pollinia*, *Kermes*, *Gossyparia*, *Eriococcus*, *Dactylopius* (Pseudococcus), *Ripersia*, are the important genera, the common Mealy-bugs being species of the genus now known as *Pseudococcus*.

Tachardiinæ. *Tachardia* includes the insects providing the lac (shellac, etc.) of commerce. The commercial product is limited to India, Burma, Siam, and Tonkin. There is a small literature on lac in India.

Coccinæ. *Pulvinaria psidii* and *P. vitis* are important economically, as also *Ceroplastes*. *Coccus*, formerly *Lecanium*, includes many species destructive in the tropics, notably *C. viride* on coffee; so also *Eulecanium* and *Saissetia*.

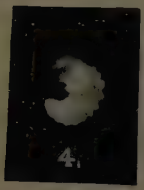
Diaspinæ. Shield Scales or Armoured Scales. In these the insects are concealed under a scale formed of part of the first or first two moults with added felted material. The important genera are *Chionaspis*, *Diaspis*, *Aulacaspis*, *Fiorinia*, *Aspidiotus*, *Chrysomphalus*, *Lepidosaphes* (Mytilaspis), *Parlatoria*.

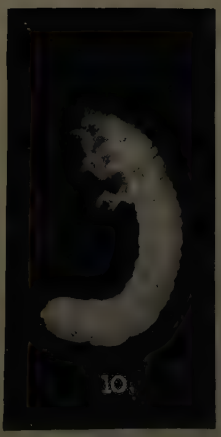
A separate sub-family has been formed for the Australian *Brachyscelinæ*, placed in Fernald as *Apiomorpha*, etc., in *Dactylopiinæ*. These are gall-inhabiting species of Australia.

The economic student will be well advised to be able to identify his species from whatever local monograph or list there is. The mounting instructions of Green (*Ann. App.*

Biol. I, 1914) are valuable ; clues to possible genera in Green's List of Food-plants appearing in the above publication from 1917 may be of help in saving time.

The treatment of Coccids as pests depends upon a study of food-plants, a study of natural enemies, direct attack by spraying or fumigating. The elimination of wild food-plants and the intelligent use of checks imported from the indigenous area, or from other infested areas, are probably the methods of the future.





[*Photos by C. L. Withycombe.*

PLATE II. MECOPTERA, MEGALOPTERA AND *ITHONE*.

1. *Panorpa communis* imago ♀ (× 2). Panorpidæ.
2. ,, ,, larva (× 2). ,,
3. *Boreus hyemalis* imago ♀ (× 4). Boreidæ.
4. ,, ,, larva (× 4). ,,
5. *Bittacus tipularius* (× 2). Bittacidæ.
6. *Sialis lutaria* imago (× 2). Sialidæ.
7. ,, ,, larva (× 1½). ,,
8. *Raphidia maculicollis* imago ♀ (× 2). Raphidiidæ.
9. *R. notata* larva (× 2). Raphidiidæ.
10. *Ithone fusca* larva (× 2). Ithonidæ.

[*To face p.* 288.

MEGALOPTERA (*Perlaria*)

Alder-flies and Snake-flies.

Wings net-veined, equal or sub-equal. Larva with simple biting mouth-parts.

This order, including two families, the *Sialidæ* and *Raphidiidæ*, has been separated from the rest of the *Neuroptera* on structural differences, which are especially noticeable in the earlier stages.

There is a large, strongly chitinized head with compound eyes, and sometimes ocelli. Antennæ are long and simple, or as in *Chauliodes*, pectinated. Mandibles, maxillæ, etc., are all well developed and of primitive biting type. The prothorax varies somewhat in form, but is generally well chitinized. Wings are very like those of *Neuroptera* with many longitudinal and cross-veins. The legs are simple, adapted for walking, with two tarsal claws. Abdomen stout; female in *Raphidiidæ* with an exserted ovipositor (Plate II, Fig. 8). Colour dull.

The larva (Plate II, Figs. 7 and 9) is most distinctly different from the very uniform larva of the *Neuroptera*. It much resembles a carnivorous coleopterous larva and has masticatory mouth-parts with well-developed mandibles and maxillæ. There is no approach to the piercing and sucking type of the Ant-lions and Lace-wings. Both head and prothorax are strongly chitinized and of large size; the rest of the body is softer and tapers to the extremity. Legs are well-developed and have two tarsal claws.

The internal anatomy presents several interesting points. In both families *Sialidæ* and *Raphidiidæ* there is a food reservoir to the œsophagus. There are six Malpighian tubules, and in *Raphidia* four of the six form loops. Thus we have an approach to the condition found in *Neuroptera* proper.

The life-history is fairly uniform; Sialids are aquatic and Raphidiids terrestrial or arborial. There are about six larval

moults before pupation. No cocoon is spun by the larva, and the pupa is free. Winter is frequently passed in the larval state.

Checks on these insects are of the usual order: insectivorous animals and parasites. Their economic importance is very slight. Sialids form part of the food of fishes. *Raphidiidæ* have been introduced into Australia in the hope of checking the codling moth, but it is doubtful whether they ever occur naturally in sufficient abundance to do real good.

References: *Coll. Zool. Selys.* V, 1910, Van der Weele (Sialidæ); *Genera Insectorum*, Fasc. 154, 1914, Petersen (Raphidiidæ).

There are six British species, two of *Sialis*, and four of *Raphidia*. Descriptions of these are to be found in MacLachlan's Monograph, *Trans. Ent. Soc.*, London, 1868.

Sialidæ.

Alder-flies.

Head square with fairly long antennæ; prothorax large; wings sloped over the body.

The distribution of this family is mainly temperate, but a number are found in the tropics.

They are heavy insects of dull coloration (Plate II, Fig. 6), slow on the wing and generally sluggish in habits. The body is somewhat massive in build with a large head and fairly long antennæ. The wings, which are generally smoky, have venation similar to that of the *Neuroptera*. When at rest they are sloped roof-like over the body. These insects are to be found almost entirely in the vicinity of water.

The head is large and square, with or without ocelli, but compound eyes are always present. Mandibles are of the biting type, toothed internally as a rule. They may be enormously developed as in the male *Corydalis*. The prothorax is large and square. Wings are almost equal in size, hyaline or smoky and net-veined. Walking legs are present. The larva (Plate II, Fig. 7) resembles a Carabid larva to a certain extent, the head and thoracic segments being strongly chitinized, while the abdomen is soft. Biting mouth-parts,

with well developed mandibles and maxillæ, are borne by the head, which is large and rather square. The legs are slightly fringed with hairs. There is an abdomen of nine segments tapering to a tail. The first seven abdominal segments are furnished with tracheal gills, which are filamentous, and curve upwards over the body, in *Sialis*. The number and arrangement of these tracheal gills is, however, very variable among the different forms. Of the internal anatomy it may be noted that there is a diverticulum, or food reservoir, to the œsophagus. There are six Malpighian tubules.

The family has been divided into two sub-families :—

(1) *Corydalinæ*, which have three ocelli and the fourth tarsal joint simple. These are large insects of which the two main genera are *Corydalis* and *Chauliodes*.

(2) *Sialidinæ*, which have no ocelli and the fourth tarsal joint bilobed. These are small insects mainly found in temperate climates. *Sialis* may be mentioned as type.

Corydalis cornutus of N. America has the following life-history. Pairing takes place in the middle of summer, the male using its huge mandibles to hold the female. About 3,000 eggs are laid by a single female, in flat patches on leaves overhanging water. The larva drops into the water on hatching, and is carnivorous. In form it is very like the larva of *Sialis*, but there are eight pairs of bushy abdominal gills, each gill tuft having by the side of it an additional longer filament. The winter is passed as a larva, and in early summer it leaves the water, making a cell in the earth under a log or stone, in which to pupate. There are six moults before pupation. The pupal stage is short and the fly emerges a few weeks later. (A. S. Packard, Junr.)

Sialis (Plate II, Fig. 6) has a very similar life cycle, eggs to the number of two or three thousand being laid in dark masses on leaves near water. The egg is cylindrical with a stalked knob at one end. Larvæ hatch and live in mud at the bottom of ponds, feeding on worms and other soft-bodied animals. When full fed they leave the water and pupate, either in a cell excavated in the bank, or often in decaying logs near the water's edge. There is no cocoon and the legs of the pupa are freely movable. The fly emerges in a few weeks after pupation, and may be found from the beginning of April until

June. There is one brood in the year. Winter is passed as a larva.

Alder-flies, both as larvæ and imagines, are preyed upon by fish and birds. The eggs are parasitized by various *Hymenoptera*, especially by the well-known fairy-flies.

Reference : Van der Weele, *Coll. Zool. Selys.* V, 1910.

In Britain we have two species of *Sialis*, *S. lutaria* and *S. fuliginosa*. (See MacLachlan, 1868.)

The family is of no economic importance.

Raphidiidæ.

Snake-flies.

Head and prothorax elongated. Female with a long ovipositor.

Distribution almost entirely Palearctic and Nearctic.

Snake-flies (Plate II, Fig. 8) can at once be recognized in the field by the curious neck, formed by the prothorax. When at rest this neck is raised and the head depressed, giving a very characteristic attitude. Flight is weak ; the wings are transparent and net-veined, when at rest being held roofwise over the body. The colour of the body is dark brown.

Both head and prothorax are strongly chitinized ; mandibles powerful and toothed on their inner margins. The antennæ are simple, slender and usually about half the length of the wings. There is a pair of compound eyes ; ocelli may be present (*Raphidia*) or absent (*Inocellia*). The prothorax is sub-cylindrical and long. Wings are of Neuropterous pattern with a distinct pterostigma. There are six walking legs. In the female there is a long exserted ovipositor (Plate II, Fig 8).

The salivary glands are long and tubular. There is a food reservoir as in *Sialidæ*. Four out of the six Malpighian tubules are attached at their extremities to form loops.

Eggs are laid by the female with her slender ovipositor in cracks in the bark of trees. The eggs are rather elongate and have a stalked knob as in *Sialidæ*. The larva (Plate II, Fig. 9) resembles a Carabid larva. Both head and prothorax are

strongly chitinized. The abdomen is soft. There are biting, carnivorous mandibles, short antennæ and simple eyes. The body is very flexible, and the larva can wriggle rapidly backwards, using the tip of the abdomen as an additional leg. Larvæ live under the bark, or in crevices, and feed on small insects and larvæ. They can fast for quite long periods, and may pass two or more years as a larva if food is scarce. The pupa lies in a slight cell or cavity under the bark; there is no cocoon. At the end of this stage, the pupa crawls out of its cell and for a short distance up the trunk of the tree, before the imago appears. There is never more than one brood in the year; the insect generally hibernates as a larva, but *Raphidia maculicollis* passes the greater part of the winter in the pupal state (C. L. W.). As checks may be mentioned fungal (e.g. *Empusa lampyridarum*) and Hymenopterous parasites, which attack the larva.

There are several monographs on the family; see Navas, *Arch. Inst. Catalan*, 1918, and Petersen, *Gen. Ins.* Fasc. 154 (1914). Albarda monographed the *Raphidiidæ* in *Tijdschr. Entom.* XXXIV, 1891.

We have four British species of *Raphidia*: *R. notata*, *R. xanthostigma*, *R. cognata*, and *R. maculicollis*. The British work on the family is that of MacLachlan (1868).

NEUROPTERA (*Planipennia*)

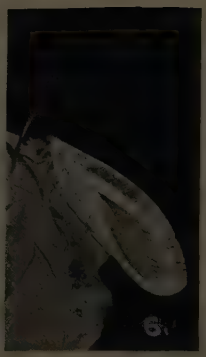
Lace-wings and Ant-lions.

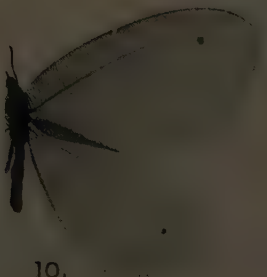
Wings net-veined, equal or unequal. Larva with mouth-parts modified for piercing and sucking.

The order Neuroptera, as now restricted, contains sixteen families. A number of these were previously included in the one family *Hemerobiidæ*, but many, notably the *Ithonidæ* and *Nymphidæ*, are so distinct as certainly to warrant family rank. The sequence adopted here agrees with that of Tillyard. The families are: *Ithonidæ*, *Hemerobiidæ*, *Dilaridæ*, *Sisyridæ*, *Coniopterygidæ*, *Psychopsidæ*, *Polystœchotidæ*, *Osmylidæ*, *Berothidæ*, *Chrysopidæ*, *Apochrysidæ*, *Mantispidæ*, *Nymphidæ*, *Nemopteridæ*, *Myrmeleonidæ*, *Ascalaphidæ*.

The order is remarkably homogeneous. In the imago there is a distinct head with mandibulate mouth-parts, large, or fairly large antennæ, compound eyes, and sometimes ocelli. The prothorax is always distinct and well developed. The wings are net-veined, usually with a complicated system of venation. Legs are simple or modified, as in *Mantispa*. Internally there is a food reservoir as a diverticulum of the œsophagus, and eight Malpighian tubes.

The larva is predaceous and feeds on other insects and the like, in some cases on sponges (*Sisyra*). The head bears simple eyes, composed of groups of ocelli, and short antennæ. Each mandible is grooved on its ventral side, and against this groove the maxilla is pressed in such a way as to form a complete tube. The larva is thus furnished with a pair of tubular sucking jaws, by means of which it can extract the juices of its prey. There is no maxillary palpus, but labial palpi are generally present. The mouth is partly closed and all nutriment is taken in fluid form through the jaws. The thorax is soft and not chitinized as in *Megaloptera*. There are six legs, each with two tarsal claws. The alimentary canal is fairly simple, but there is no communication between the pyloric end of the stomach and the anus. All solid waste is therefore





[*Photos by C. L. Withycombe.*

PLATE III. NEUROPTERA.

1. *Ithone fusca* imago (× 2). Ithonidæ.
2. *Conwentzia psociformis* imago (× 4). Coniopterygidæ.
3. ,, ,, larva (× 4). ,,
4. *Boriomyia subnebulosa* imago ♂ (× 4). Hemerobiidæ.
5. ,, ,, larva (× 4). ,,
6. *Chrysopa septempunctata* imago (× 1½). Chrysopidæ.
7. *C. flava* larva (× 4), Chrysopidæ.
8. *Osmylus chrysops* imago (× 2). Osmylidæ.
9. ,, ,, larva (× 4). ,,
10. *Psychopsis zebra* imago (× 2). Psychopsidæ.

[*To face p.* 295.

stored in the mid-gut, and is evacuated in a mass during the early part of imaginal life. There are eight Malpighian tubules, and of these six have their distal ends united and lead to a reservoir which communicates with the anus. At the end of the larval period the greater part of each of the looped Malpighian tubules becomes differentiated as a silk-secreting gland, and the nuclei of the cells so specialized become ramified as in true silk glands. The silk secreted collects in the reservoir and is spun out through the anus when the cocoon is constructed. This structure is found in all the *Neuroptera*, and although modification of the mouth-parts occur, the principle is always the same.

The life-cycle varies considerably, but the larva is always predaceous. There are three larval instars, except in *Ithonidæ* with five and *Croce* reported with two. A cocoon is spun by the larva, and is usually remarkably small compared with the size of the larva and of the emerging insect. The pupa is quiescent, but all the limbs are freely movable in late pupal life. It is provided with special mandibles with which to cut its way out of the cocoon.

The order is wholly beneficial to man. This applies especially to the *Hemerobiidæ*, *Coniopterygidæ* and *Chrysopidæ*, which check Aphids, Coccids, mites, etc.

Monographs on the families of the *Neuroptera* are mentioned under each. A general classification is given by R. J. Tillyard, *Proc. Linn. Soc. N.S.W.*, 1918.

In Britain we have representatives of *Hemerobiidæ*, *Sisyridæ*, *Coniopterygidæ*, *Osmylidæ*, and *Chrysopidæ*. For accounts see MacLachlan, *Trans. Ent. Soc. Lond.*, 1868.

Ithonidæ.

Moth lace-wings.

Stout-bodied insects with large heads, filamentous antennæ, and narrow equal wings.

The *Ithonidæ* are native to Australia and Tasmania, but have been introduced into New Zealand. These insects (Plate III, Fig. 1) bear considerable resemblance to the *Hepialidæ* among moths, but no scales are present. They are

of dingy colours and probably approach the *Megaloptera* more nearly than any other of the *Neuroptera*. When at rest the wings lie close to the body. The legs are short, but *Ithone* can run rapidly like a cockroach.

The head is large and sessile on the prothorax. There are well-developed biting mandibles which are not toothed internally. Those of the male are longer and sharper than those of the female. The maxillæ have five-jointed palpi, the labium is reduced and bears a pair of long three-jointed palpi. Antennæ are filiform and tapering, prominent compound eyes are present, but ocelli are wanting or vestigeal. The thorax is stout, the wings are narrow and usually dark brown in colour. When at rest they are roofed over the body. There are one or more radial sectors and a humeral recurrent vein is present. Legs are short, each with a five-jointed tarsus and bilobed empodium. The abdomen is stout. Males are smaller than females and can be recognized by the genitalia.

Eggs are laid in sand and are large, oval and soft: being covered with a sticky material the sand grains adhere to them. The larva is a soft, whitish, burrowing, blind, Melolonthoid grub (Plate II, Fig. 10). Mandibles and maxillæ are, as usual, adapted for sucking, but are short and of simple form. This larva passes a subterranean existence, feeding upon other larvæ, as for example those of Melolonthid beetles. There are five larval instars. The pupa is enveloped in a cocoon and is also under sand. When about to emerge the pupa escapes and makes its way to the surface.

The family has been reviewed by Tillyard, *Trans. Linn. Soc. N.S.W.*, 1919, and the life-history of *Ithone* described (*Bull. Ent. Res.*, 1922).

Economic importance slight, but beneficial.

Hemerobiidæ.

Brown lace-wings.

Antennæ long, moniliform. Wings with at least two radial sectors. Subcosta runs into margin of wing and not into radius.

This family is of world-wide distribution. The *Hemerobiidæ* are delicate Neuropterous insects (Plate III, Fig. 4), usually

coloured in browns. They frequent woods mainly. Some approach the *Lepidoptera* in form, e.g. *Drepanepteryx*, which strongly resembles a Drepanid moth, but the wings are never scaly. When at rest the wings are held steeply roof-like over the body, the antennæ being stretched out in front in a straight line. Habits are mainly nocturnal, but flight by day is by no means uncommon, especially on disturbance.

The head is furnished with compound eyes. Antennæ are moniliform ; mouth-parts biting. The prothorax is frequently longer than either of the other two thoracic segments, but not as long as in *Chrysopidæ*. The wings have many veins and are of the usual type. Sex determination is by means of the genitalia, which are as a rule easily visible externally.

The larva (Plate III, Fig. 5) is somewhat elongated, but really quite typical in both external and internal structure. The mandibles and maxillæ unite to form a tube, but the sucking jaws thus formed are fairly short and stout, inwardly curved. They are simple and not toothed. The head itself is relatively small, and is provided with short filiform antennæ and simple eyes. The body is naked except for very minute hairs. There are three pairs of walking legs, and the anal extremity is used as an additional leg when in motion. In the larval state there is no external opening to the alimentary canal, and the anus is used as a spinneret for silk secreted by the Malpighian tubules.

Eggs are generally laid singly, attached by their sides to leaves and twigs of trees. They are of long oval shape, averaging about $\frac{1}{2}$ to 1 mm. in length. At the micropylar end is a small knob. The larva escapes by a rent in the eggshell and feeds on small *Rhynchota* and mites. There are three larval instars ; pupation occurs in a loosely woven, elliptical cocoon spun by the larva among leaves, or in crevices of tree bark, or in moss on the ground. The pupa tears a hole in the cocoon and climbs to a suitable position before the imago appears.

Larvæ of Hemerobiids are attacked by several Hymenopterous parasites. Birds, ants and spiders prey on the adults.

A revision of the Nearctic *Hemerobiidæ* is given by Banks in *Trans. Amer. Ent. Soc.*, 1906. For classification see Krüger, 1922. Navas has published a table of genera and tribes in Broteria 9 (1910). MacLachlan monographed the British

forms in 1868, and published further notes in *Ent. Mo. Mag.*, 1899. See also Withycombe, 1922.

The *Hemerobiidæ* are wholly beneficial to man and often occur in large numbers on forest trees, acting as checks on Aphids, Jassids, etc.

Dilaridæ.

Antennæ of male pectinated, female with a long exserted ovipositor.

These insects are found sparsely in most parts of the world. In general appearance they resemble the Hemerobiids, but the pectinate antennæ of the male and the long ovipositor of the female at once separates them.

The head has three tubercles on the vertex which much resemble ocelli. Prothorax transverse, wings entire with four or more radial sectors. The subcosta ends in the margin of wing and does not run into the radius. Gradate veinlets are irregular. In the female the hind-wings tend to atrophy. Metamorphoses apparently not known. The long ovipositor of the female suggests a similar habit of life to that of *Raphidia*, but the imagines are generally found near water.

The family has been monographed by Navas, *Gen. Ins.* 156.

Sisyridæ.

Small brown insects resembling Hemerobiids, but with one radial sector. The subcosta runs into the radius in the region of the pterostigma.

The *Sisyridæ* are mainly North Temperate in distribution. Though their general appearance is the same as that of Hemerobiids, the *Sisyridæ* are quite different in habits, being entirely aquatic as larvæ. They are usually dark brown in colour, the wings being, as a rule, unspotted. Antennæ are moniliform and simple. There are no ocelli. The last joint of the labial palpi is swollen. In the wings, there is one radial sector, which does not generally branch more than twice. Costal veinlets are simple, there is no recurrent humeral vein, no gradate series, and very few cross-veins.

Eggs are of Hemerobiid forms, ·35 mm. long, laid in groups

and covered by a thin layer of silk by the female. The larva lives in or upon sponges. It has very much elongated, needle-like, but flexible mandibles and maxillæ. On the ventral surface of each of the first seven abdominal segments are a pair of jointed, leg-like, tracheal gills. When full fed the larva leaves the water and spins a small cocoon of silk on walls or amongst herbage, etc. From this, in due course, the fly emerges. (Withycombe, 1922).

Three species of *Sisyra* are found in the British Isles: *S. fuscata*, *S. terminalis* and *S. Dalii*. These have been treated of by MacLachlan, 1868.

Coniopterygidæ.

Mealy-wings.

Very small, the entire insect covered with a white waxy powder. Wing venation simple. Hind-wings always smaller than fore-wings and sometimes much reduced.

Species of this family are recorded from most parts of the world. They are small flies (Plate III, Fig. 2), averaging an eighth of an inch in length with wings at rest. They resemble the *Aleurodidæ* as the wings and body are covered with a white waxy powder; they can, however, at once be distinguished by their long antennæ, biting mouth-parts and more complex venation. The wings at rest are carried steeply roofwise over the body. Flight is weak and of short duration.

The head is relatively large with long moniliform antennæ, compound eyes and biting mouth-parts. Legs are well developed, and the insect can run rapidly. The wings have a fairly simple venation with very few cross-veins and are covered with the white waxy powder common to the whole insect. In the genus *Conwentzia*, the hind-wings are considerably reduced. The tribe *Aleuropteryginæ* is remarkable in that these insects have a pair of curious eversible ventral sacs on each of abdominal segments one to five, and a rudimentary pair on the sixth abdominal segment. These are situated just below the spiracles; their function is unknown.

The larva (Plate III, Fig. 3) is ovoid or fusiform with well-developed legs. The mouth-parts are somewhat modified from

the usual type found in this order, being reduced to a conical form, but in working principles they are quite in accordance with the rest of the Neuroptera.

The insects are semi-gregarious, and where found are often plentiful, oak trees especially are frequently covered with the white cocoons of *Conwentzia*. Eggs are generally laid singly on the edges of leaves or on the twigs and bark. The egg is of an elongated oval shape slightly flattened and lies attached by its side to a surface. At the micropylar end it may be pointed. Colour when first laid is yellow or orange. Larvæ hatch in about a week and feed voraciously on mites and small *Rhynchota*. On oaks they constitute an important check on the *Phylloxera*, in virtue of their great abundance. The larva runs rapidly about, piercing its prey with the conical sucking spears and extracting all fluid matter. The body of the larva is naked, save for small hairs. There are three larval instars. When full fed a flat circular cocoon of white silk is spun which consists of two envelopes, an outer and an inner. This the larva constructs by moving the anal spinneret to and fro over its back, having first selected a suitable position on the underside of a leaf or on the bark of the tree. The pupa on emerging from the cocoon cuts a semicircular slit in both envelopes, and the perfect insect emerges from the pupal skin. There are usually two broods in the year. The late summer brood of larvæ always spin on the bark of the tree and never on the leaves. Winter is passed as a larva within the cocoon, pupation not occurring until spring. These insects are entirely confined to trees and woody shrubs. Several Hymenopterous parasites attack the larvæ. Chrysopid larvæ prey on both larvæ and pupæ of *Coniopterygidæ*.

The family was monographed by Enderlein, *Zool. Jahrb.*, 1906, and there is a catalogue of the genera by the same author in *Gen. Ins.* 67, 1908. Bagnall had a brief review of the European species in *Ent. Rec.*, 1915, see also Withycombe, 1922, 1923. As British there are recorded two species of *Conwentzia*, two of *Coniopteryx*, one of *Semidalis*, one of *Parasemidalis*, and one of *Helicoconis*.

This family is wholly beneficial to man, and the insects, when abundant, may act as a very appreciable check on the smaller noxious fauna of trees.

Psychopsidæ.

Wings very broad with rounded apices. Subcosta, radius, and radial sector run together closely parallel, forming the vena triplica, which is quite characteristic. Antennæ short.

The *Psychopsidæ* are mainly Australian and African in distribution. In appearance (Plate III, Fig. 10) they are so distinct that it would be difficult to confuse them with any other insects. The wings are very broad and have a soft, hairy appearance. When at rest they are roofed over the body. Antennæ are short and quite inconspicuous. The head is of medium or small size, with lateral compound eyes and no ocelli. The mandibles are small; maxillæ with five-jointed palpi; labial palpi three-jointed. The legs are short; tarsus five-jointed with a broad empodium between the claws. The wings are very broad and rounded. Costal area wide, with no differentiated pterostigma. The subcosta, radius, and radial sector run closely together as the *vena triplica* and form the *anastomosis* a short distance from apex of wing. A series of cross veinlets runs in the costal area and outside the outer gradate series, thus cutting off a margin round the wing. This and the *vena triplica* are particularly noteworthy in the Psychopsid wing. The abdomen is short and fairly stout.

The larva has a large, strongly chitinized, chestnut-brown head, with a pair of untoothed, curved, caliper-like sucking jaws. Between the jaws is a triangular, projecting labrum. The long antennæ are ten-jointed, and labial palpi five-jointed in the third-instar larva. The rest of the body is soft and greyish-brown in colour. It is slightly flattened, fairly long, and tapers posteriorly. The legs are short, fitted for backward movement and possess, between the two tarsal claws, a trumpet-shaped empodium, as also found in Chrysopid larvæ.

The life-history of *Psychopsis elegans* Guer. is as follows: Eggs are laid, attached by their sides, on the bark of Myrtaceous trees, especially on *Eucalyptus*. They are oval, with a micropylar projection and are about 1 mm. in length. Their colour is cream, tinged with green. Oviposition takes place in January and February in Australia. After about twelve days the young larva hatches and at once conceals itself in a crevice

of the bark. It lives in this way, under bark much as does the larva of *Raphidia*, and like the latter prefers moving backward in its retreat. Any small insects are accepted as food, being sucked dry by the curved jaws. The first winter is passed as a first-instar larva, the second winter in the third instar, and in the following spring an almost spherical cocoon of cream coloured silk is spun in a crevice. On emergence the pupa cuts with its jaws, which are asymmetrical, a circular lid in the cocoon, and pushing this open ascends the tree trunk a short distance before disclosing the imago.

Birds have been observed to feed upon the imagines.

Tillyard gives an account of the *Psychopsidæ* in *Proc. Linn. Soc.* N.S.W. 1918, and the life-history of *P. elegans* in the same proceedings for 1919.

These insects are too rare to be of any economic importance, though they are wholly beneficial. There are no British species.

Polystœchotidæ.

Wings ample, sub-acute, speckled with black or brown. The subcosta runs into the radius near pterostigma. One radial sector with ten to twenty branches. Humeral vein recurrent.

Polystœchotes punctatus is fairly common in North America, and appears to have similar haunts to those of *Osmylus* in Europe.

In general appearance *Polystœchotes* is like a large Hemerobiid with rather short antennæ and slightly more acute wings. It expands about two and a half inches. The main venational characters have been mentioned.

Welch (*Bull. Brooklyn Ent. Soc.* 1914) says that the eggs are oval, chalk-white in colour, and ·92 to ·94 mm. long. The larva hatches in fifteen days, and is apparently very like a Hemerobiid larva with short and stout inwardly curved jaws, but the antennæ have more joints than Hemerobiids—eight on hatching. Welch believes that the larva is terrestrial.

Life-history not fully known. Banks in his Revision of the *Nearctic Hemerobiidæ*, 1906, gives an account of *Polystœchotes punctatus*. There are no British species.

Osmylidæ.

Fore-wings, which tend to be somewhat falcate, with one radial sector. The subcosta is confluent with the radius at apex. The humeral cross-vein is not recurrent. Head with three ocelli.

The *Osmylidæ* have almost a world-wide distribution, but are not recorded from North America. They are insects of moderate size, found near water. Colour brown, wings often spotted or marked with darker. The subfalcate wings are characteristic (Plate III, Fig. 8). The sexes are similar.

The head has three ocelli and moniliform antennæ which are shorter than the wings. Prothorax longer than broad. Wings with subcosta and radius confluent near pterostigma, and other characters as above.

Eggs are laid near water, the egg being 1·5 mm. long, yellowish-white, oval, with a white knob at the micropylar end. The larva (Plate III, Fig. 9) is amphibious, of general Hemerobiid shape, but with long, almost straight sucking spears. The mandibles and maxillæ are much elongated, curved upwards and slightly outwards. The larva preys upon other insects and lives among damp moss, etc., at or near the water's edge. When almost full fed the larva hibernates, and in spring or early summer an irregular rounded cocoon of silk is spun in moss or debris. The imago is sluggish, only flying by day on disturbance.

The family has been monographed by Krüger in *Stettiner Ent. Ztg.* 73 and 74, 1913.

We have only one British species, *Osmylus chrysops*. This is mentioned by MacLachlan in his monograph of 1868.

No economic importance can be attributed to the *Osmylidæ*.

Berothidæ (including *Trichomatidæ*).

Fore-wings frequently falcate, scales often present on wings. Otherwise rather similar to Hemerobiidæ.

The *Berothidæ* are fairly generally distributed throughout the world, but appear to be nowhere common. They are

mostly dingy brown in colour, and but for small venational characters are hardly distinguishable from Hemerobiids, with which in fact they have been generally classed.

Little need be said as to their structure, which in most points does not differ from that of other *Neuroptera*. The wings are worthy of notice, however, as those of many species have scaly areas. Thus females of *Spermophorella* have a scale area on the veins of the hind-wings, while the fringes of the wings in *Isoscelipteron* are composed partly of scales. These scales are modified macrotrichia. The venation varies throughout the family.

Tillyard gives an account of eggs and young larvæ of *Spermophorella* in *Proc. Linn. Soc. N.S.W.* 1916. The eggs are stalked and very like those of *Chrysopa*. The larva is terrestrial with short, straight jaws.

References to the *Berothidæ* may be found under *Hemerobiidæ*. Tillyard gives a short account of the venation, scales, etc., in *Proc. Linn. Soc. N.S.W.* 1918–1919, and Krüger a classification in *Stett. Ent. Zig.*, 1922.

Chrysopidæ.

Green lace-wings, Stink-flies, Golden eyes.

Colour generally green. Antennæ filiform, long. Wings hyaline, subcosta and radius separate to the apex, subcostal area with one transverse veinlet near the base, and several at apex near pterostigma. No recurrent humeral vein.

Distribution of the family is both temperate and tropical. The flies are generally greenish in colour, with golden eyes (Plate III, Fig. 6). The antennæ are long and the wings delicate, transparent, with many cross veins. Both pairs are almost equal in size. When handled these insects frequently give off a very disagreeable odour, from prothoracic glands, which it is difficult to get rid of. They are mainly nocturnal in habits and are attracted by light.

A pair of long filiform antennæ and large compound eyes, generally of metallic golden colour in life, are the main features of the head, which is also provided with biting mouth-parts. The prothorax is rather long. The wings are delicate and net-

veined, most frequently hyaline and not marked. Both pairs are almost equal in size. The main venational characters have been mentioned. The legs are short and frail. Abdomen elongate. The sexes are often difficult to determine except by dissection, as the genitalia are frequently concealed.

The larva (Plate III, Fig. 7) is as a rule stouter than that of *Hemerobius*, and some larvæ are covered with setigerous warts. Between the two tarsal claws is a trumpet-shaped empodium which is not found in full and half-grown Hemerobiid larvæ. The sucking jaws are of the general type, curved and untoothed.

Internal anatomy presents no great differences from that of other *Neuroptera*. There is a food reservoir to the œsophagus in the imago. The larva has no functional anus, but uses the same as a spinneret in constructing its cocoon.

Eggs are laid, each at the end of a long footstalk, attached to the underside of leaves, etc., where aphids are abundant. These eggs may be found singly or in masses, and in some species the footstalks are so close together as to be agglutinated into a common stalk. The larva escapes by a rent in the egg-shell, and if any unhatched eggs are present, makes its first meal off these. The larvæ are fiercely carnivorous, piercing their prey with their sucking jaws and extracting the juices. They feed mainly on Aphids, Psyllids, and Jassids, but many subsist also on Coccids and mites. Chrysopid larvæ frequently have the habit of covering themselves with Aphid skins and other debris, which they carry about with them, but some larvæ are always nude, like those of Hemerobiids. At the end of the third instar the larva spins a small white oval cocoon in which to pupate. The pupa, when escaping from its cocoon, cuts a circular slit at one end with its pupal mandibles and, pushing open the lid thus formed, walks a short distance before the imago is disclosed.

The number of broods each year varies with the temperature. In England, Chrysopids are single, or at most double-brooded, but in warmer climates four or five broods seem to be the rule. The species hibernate in all stages, except perhaps in the eggs. Usually the winter is passed as a larva within the cocoon, pupation not occurring until the following spring. Lace-wings

are found mainly in orchards and woods, but the larvæ of some species live on low plants.

As checks, one finds several Hymenopterous parasites which lay their eggs either in the eggs or larvæ of Chrysopids. Numbers of the flies are often seen in spiders' webs, and a few may be eaten by birds, but they are probably distasteful owing to their disgusting smell.

Very little systematic work of a comprehensive nature has been done recently on the *Chrysopidæ*. Schneider monographed the family in 1851. Since then, Navas has published notes on various species and he gives a table of genera and species in Broteria 9.

The best British work is still that of MacLachlan (1868). There are thirteen species of *Chrysopa* and two of *Nothochrysa* found in Britain.

The family is of considerable economic importance, since the larvæ prey entirely upon Aphids, Coccids, etc.

Apochrysidæ.

Very like Chrysopidæ, but there is no transverse veinlet near the base of the subcostal area.

The *Apochrysidæ* are exotic forms about which very little appears to be known. In life-history, as also in general appearance, they probably approach the Chrysopids, with which they have been classed by most authors.

The antennæ are sometimes exceedingly long. The wings are very like those of Chrysopids, but there is a tendency to reduction in the width of the hind-wings. There are three or even four gradate series, and often curious "blisters" occur upon the wings. References to this family will be found under *Chrysopidæ*.

Mantispidæ.

Prothorax long, fore-legs raptorial.

This family is distributed throughout the tropics, but a few species are found in warm temperate regions. Mantispids (Plate IV, Fig. 7) might easily be mistaken for Mantids, to

which they bear a considerable resemblance. All are, however, of small size; the wings are typically Neuropterous and are roofed over the body. The fore-wings are in no way thickened as tegmina. General colour is brown, but some have warning coloration and mimic *Hymenoptera*.

The head is rounded, with compound eyes and a pair of short antennæ, which are simple. Mouth-parts are of mandibulate type. The prothorax is much elongated and the raptorial fore-legs are situated near the head. These legs are very similar to those of the *Mantidæ*. The coxæ are long, the femur is thickened and spiny. The tibia folds like a clasp-knife on to these spines and thus constitutes an admirable organ of prehension. The tarsus is quite small. Meso- and metathorax are both short and bear ordinary walking legs. The two pairs of wings are membranous, often transparent, with netted veins, and are almost equal in size.

The larva is at first campodeiform, but later becomes a fat grub with reduced legs. The mouth-parts are short but sharp and adapted for piercing.

The female insect lays its eggs in a similar way to *Chrysopa*, each egg being borne on a slender footstalk.

On hatching in autumn the larvæ are active and somewhat like Carabid larvæ, but of course with totally different jaws. They moult once and then hibernate without having taken food. In spring, activity is resumed and each larva searches out the egg-cocoon of a spider (*Lycosa*). This is entered by the larva and when the spider's eggs have reached a certain stage in development, the young *Mantispa* commences feeding on them. The next moult reveals an almost legless grub, which has a small head and which is quite incapable of locomotion. In a few days it is full fed and spins a cocoon inside that of the spider. The pupa does not cast the larva skin, but remains inside it. Finally the pupa tears its way out from all its envelopes and emerges from the spider's egg-bag. On reaching a suitable support the imago appears. It should be noted that only one *Mantispa* larva lives in a single egg-bag, and also that the *Lycosa*, who personally guards her eggs, does not desert them until the *Mantispa* has pupated.

Above is the account given by Brauer of the European species; some tropical forms, however, parasitize the nests of

Hymenoptera, one South American species living in the nest of a wasp.

Enderlein gives a classification of the *Mantispidæ* in *Stett. Ent. Ztg.* 1910. Brauer wrote on *Mantispa* in *Verh. Zool. Bot. Ges. Wien.* 1869, and in *Zool. Anz.* 1887, besides various other accounts.

In Britain we have no Mantispids.

Nymphidæ.

Wings and general appearance very like Myrmeleonidæ, but antennæ filiform and not clubbed.

The *Nymphidæ* are entirely confined to Australia. At first sight one would certainly consider one of these insects to belong to the *Myrmeleonidæ*, the likeness being very striking (Plate IV, Fig. 1), but the antennæ are simple and not clubbed, and they are also usually slightly longer than those of the Myrmeleonids.

The head is large and distinct with biting mouth-parts and fairly long maxillary and labial palpi. The antennæ are filiform, nearly half as long as the wings and tapering at their apices. There are no ocelli. The prothorax is slightly longer than broad. Legs are well developed, with two tarsal claws and bilobed empodium. The wings are ample with a venation very similar to that of the *Myrmeleonidæ*. The costal veinlets in the region of the pterostigma are very close together and extend thus from the pterostigma round the apex of wing, giving a characteristic appearance. The same formation occurs in *Myrmeleonidæ*, but usually less noticeably. The abdomen is slender. The external genitalia of the male are quite conspicuous, but the claspers are not long and slender as in the *Myrmeleonidæ*.

The larvæ of *Nymphes myrmeleonides* live in rubbish or on overturned logs. The body is covered with particles of earth, so that only the front of the head and jaws are exposed. They rest motionless, but can move quite rapidly when disturbed. From the situations in which they occur, their food probably consists of wood ants. When full fed the larva is two-thirds of an inch long. The head is furnished with long curved jaws,

each with a single tooth on its inner margin, about half-way from the tip. The eyes are composed of six facets and project near the base of the jaws. The hind margin of the head has two rounded lobes. The antennæ are filiform, with a short basal joint. The head is connected to the thorax by a slender neck and the prothorax is produced into two lobes projecting on either side of the head. These lobes, together with the rest of the thorax, form a shield-shaped plate. Legs are long, slender, and hairy, with large claws. The abdomen is narrow at the base, elongate oval, with a short pointed tubercle standing out in the centre of each segment. The entire abdomen is coated with hairs and fringed at the sides with longer hairs.

A round parchment-like cocoon is spun for pupation.

There is no recent work on the *Nymphidæ* except descriptions of species. The account of the larva given above is from Froggatt, *Proc. Linn. Soc. N.S.W.* 1902.

Nemopteridæ.

Hind-wings very long and narrow. Antennæ elongate, not clubbed.

In tropical and sub-tropical countries these elegant insects may be seen at dusk, dancing in small groups, in secluded and sheltered spots, much in the same way as do the familiar "winter gnats" and some Tipulids in this country. The wings may be colourless or marked with yellow and black. The fore-wings (Plate IV, Fig. 3), which are broad, are used in flight, the long hind-wings being trailed. When at rest the wings are opposed to one another, as in the case of butterflies.

The head bears antennæ which, though they may be thickened in some cases, are not clubbed. Mouth-parts are in the form of a beak, the clypeus and genæ being elongated. The legs are short and frail. Fore-wings are of typical Neuropterous pattern and very broad, but the hind-wings have the venation reduced and are long and narrow. In *Nemoptera* the hind-wings are oar-shaped, but in *Croce* they are reduced to slender filaments. The sexes may be distinguished by the external claspers of the male.

The larvæ vary greatly. In the *Crocini*, the larva has a

more or less long and narrow "neck" and toothed (*Croce*) or untoothed (*Nina* and *Ptero-croce*) mandibles. The larva of *Nemoptera* has short stout jaws and no long neck [to be described shortly (C. L. W.)]. The larva of *Ptero-croce* is figured (Plate IV, Fig. 4).

The life-history in the *Crocini* takes from one to two years. Eggs are laid in the sand of caves, or in the dust and rubbish on the floors of deserted houses or sheds. These eggs are ·5 to 1 mm. in diameter, spherical or oval, and pale yellow or greenish in colour. They are deposited in loose clusters to which the dust adheres. In from eight to twelve days the larva hatches and can at once be identified by the long narrow neck. C. C. Ghosh states that in *Croce filipennis* there are only two larval instars. If this is correct, Nemopterids differ in this respect from all other *Neuroptera*. The larvæ can run rapidly, but generally conceal themselves in the dust and await their prey. In cave-living species this consists mainly of ticks from sheep and goats, also Dermestid larvæ, etc., feeding upon bat droppings, but in such forms as *Croce*, which live in houses, the food is normally Psocids, bed-bugs, Dermestid larvæ, *Lepisma*, etc. Pupation takes place in a silken cocoon, spun in the usual way. After about three weeks the pupa forces its way out and the imago is disclosed. As has been stated before, the adult is crepuscular in habits, but it is attracted by light, and sometimes finds its way into houses at night. Winter is passed as a larva.

Navas gives the genera of the *Nemopteridæ*, and lists the species in *Gen. Ins.* 136, 1912. The same author has a monograph in *Mem. Ac. Barc.* 1910. The life-history of *Croce* was given by Ghosh in *Journ. Bombay Nat. Hist. Soc.* 1910, and by Imms, with greater detail, in *Trans. Linn. Soc. Lond.* 1911.

None of the *Nemopteridæ* are found in the British Isles.

Myrmeleonidæ.

Ant-lions.

Antennæ short and clubbed, wings net-veined.

The distribution of these insects is mainly tropical, but a few species are found in temperate regions. They are of

1.

2.

3.

4.

5.

6.

7.

[*Photos by C. L. Withycombe.*

PLATE IV. NEUROPTERA.

1. *Nymphes myrmeleonides* imago ♂ (× 1). Nymphidæ.
2. *Ascalaphus coccajus* imago ♀ (× 1). Ascalaphidæ.
3. *Nemoptera bipennis*, imago (× 1). Nemopteridæ.
4. Undescribed genus larva (× 4). „
5. *Euroleon europœus* imago (× 1). Myrmeleonidæ.
6. „ „ larva (× 2). „
7. *Mantispa* sp. imago (× 2). Mantispidæ.

[*To face p.* 310.

moderate or large size, dark in body colour, with ample gauzy wings somewhat resembling dragonflies (Plate IV, Fig. 5). None are very active, however, and their flight is weak. When at rest the wings are sloped over the body. Some species, when handled, give out an odour which may be pleasant or otherwise.

The head is large and distinct with compound eyes. Antennæ are fairly short and clubbed distally. Mouth-parts are of biting type with long palpi. Two pairs of equal wings are present, of complex Neuropterous form. The legs are short and hairy, only useful for clinging. At the extremity of the abdomen in the male are a pair of conspicuous claspers which render sex determination easy, since the female possesses no similar structures.

The larva (Plate IV, Fig. 6) is short and stout with a flat head from which arise the long curved jaws, formed, as has been explained, by the mandibles and maxillæ conjointly. The mandibles are toothed. The legs are not very well fitted for walking and often the larva can only progress backwards.

There is a food reservoir from the œsophagus and the number of Malpighian tubes is, as usual, eight. The anatomy of the larva has been the subject of much discussion and classical work, there being no functional anus. Six of the eight Malpighian tubes have their distal ends united and are partly modified as silk glands. The anus serves as a spinneret.

In most species the life cycle is completed yearly, but it may take two years in some cases, according to the amount of food obtained. Eggs, which are oval and whitish, are laid in dry earth or sand, generally singly. The site chosen by pit-making species is always protected from rain, since the larva cannot work in wet sand. Favourite positions are at the base of a house wall or under a slightly overhanging rock. The larva makes a funnel-shaped pit, at the bottom of which it lies concealed. Any insect venturing over the edge of this falls down to the jaws of the larva and is sucked dry. Some species do not construct a pit but lurk in loose earth or vegetation with open jaws. There are three larval instars. When full fed a spherical cocoon of silk is spun, to which adhere small particles of sand and rubbish. In this, the change to pupa takes place, and in two or three weeks the imago appears. The

pupa forces open its cocoon and partly emerges from it before disclosing the adult fly. Shortly after emergence a shiny pellet of urates is deposited, this being the unevacuated larval excrement. Hibernation is as a larva.

Adults are preyed upon by birds, but in some cases no doubt escape by emitting a nauseous odour.

A monograph of the *Myrmeleonidæ* is at present in course of preparation for the Selysian Catalogue, by Petersen. There are useful notes on the European *Myrmeleonidæ* by the same author in *Ent. Medd.* 1918–1919.

There are no British Myrmeleonids. The family is of no economic importance.

Ascalaphidæ.

Butterfly hawks.

Antennæ long and clubbed.

This family is mainly a tropical one, but has almost the same range as the last. The long, clubbed antennæ, held straight out from the head, are very characteristic of the *Ascalaphidæ*. Otherwise these insects bear resemblance to stout-bodied dragonflies (Plate IV, Fig. 2), and, like them, hunt insects on the wing. There are two pairs of conspicuously net-veined wings, equal in size, which may be marked in white, yellow, and black. When at rest these are held close to the body.

The head is furnished with large compound eyes which are in some cases divided. The antennæ are long and slender, each with a conspicuous terminal knob bearing sense organs. Mouth-parts are of carnivorous biting type with well-developed mandibles. The body is decidedly hairy with short clinging legs and two pairs of equal strong-veined wings. In the male there is a pair of claspers at the tip of the abdomen and this character serves to distinguish the sexes.

The larva is very like that of the ant-lion, but it is able to walk more easily as the legs are freely movable. The body is covered with branched spines. Structural details are similar to those of ant-lions, the head bearing similar sucking jaws and minute antennæ.

The internal anatomy does not differ materially from that of other *Neuroptera*.

The female insect lays eggs in rows on grass and plant stems. These are cylindrical or spheroidal, and coloured yellow or brown. The larva escapes by forcing a lid off the top of the egg, a split occurring along the line of a suture. At first the larvæ remain on the empty eggshells, but later disperse and live freely on tree trunks or on the ground, partly concealing themselves, when possible, and remaining motionless, often for days, with jaws wide open at right angles to the head. Any insect crossing this trap is immediately seized, the larva suffering itself to be dragged about rather than relinquish its hold; finally all fluid nutriment is extracted from the victim. After two moults the larva spins a cocoon of silk, which is covered with local debris and, within this, it pupates. The pupa, after some weeks, forces open the cocoon and the perfect fly emerges. Pupation takes place in spring or early summer, the larva having hibernated. The entire life-history occupies one or two years.

Van der Weele has monographed the *Ascalaphidæ* in *Coll. Zool. Selys*, 1908.

There are no British species. The family is of no economic importance.

TRICHOPTERA. Caddis-flies

Wings clothed with hairs. Hind-wings larger than fore-wings, and with a distinct anal area, folded longitudinally when at rest. Mandibles absent.

The order is divided into two main groups and thirteen families.

(1) *Inæquipalpia*, in which the male does not agree with the female in having a five-jointed maxillary palpus. This comprises three families: *Phryganæidæ*, *Limnophilidæ*, *Sericostomatidæ*.

(2) *Aequipalpia*, in which both sexes have a five-jointed maxillary palpus. This comprises ten families: *Calamoceratidæ*, *Odontoceridæ*, *Leptoceridæ*, *Molannidæ*, *Hydropsychidæ*, *Psychomyiidæ*, *Polycentropidæ*, *Philopotamidæ*, *Rhyacophilidæ*, *Hydroptilidæ*.

Members of the *Trichoptera* are found in most parts of the world in the vicinity of water. They are fragile insects, like hairy moths (Fig. 92), some of the smaller species being

FIG. 92.—*Phryganea varia*. (× 2.)
C. L. W. del.

difficult to distinguish from Tineid moths. The wings are sloped over the body when at rest. Flight is weak; colours dull.

The head is fairly large, with compound eyes and usually three ocelli. Antennæ are long and filiform. The mouth-parts are reduced. Mandibles are absent. The maxillæ and labium together form the "haustellum" of Lucas, the labrum roofing the channel. The hypopharynx serves as a tongue. Both maxillary and labial palpi are present. The prothorax is very small. Legs are long, with elongated coxæ, spiny tibiæ and tarsi, the tarsus being five-jointed. Wings are large, the fore-

wings being narrower and often marked with a pattern. The venation consists mainly of longitudinal veins, cross-veins being few. Hind-wings are nearly always large with a plicate anal area. The abdomen is of nine segments. The male has claspers.

The larva (Fig. 93) is soft-bodied with a well-chitinized head and thorax; the hind parts of the thorax are, however, often less strongly chitinized. The mouth-parts are of biting type with well-developed mandibles. Maxillæ, and labium with palpi, are also present, but vary in the extent to which they

Fig. 93.—Larva of *Phryganea varia*. (× 2.)

C. L. W. del.

are developed. The thorax has three pairs of well-developed walking legs, but one pair of these may be reduced. The abdomen is soft with filamentous tracheal gills. At its extremity are a pair of laterally placed chitinous hooks, which enable the larva to retain a firm hold on the inside silk-lined wall of its case.

The pupa, as well as the larva, possesses mandibles, but these disappear in the adult.

In the larva, the salivary glands function wholly or partly as silk glands.

Eggs are laid embedded in masses of jelly. The mass may take the form of a gelatinous rope. On hatching, the larva

at once sets to work to protect its soft body by constructing a case. To this end various materials are taken by the larva and by means of silk from the mouth are fastened together into a case. The larva may be sedentary, actively walking or swimming, herbivorous or carnivorous. Often the species may be recognized by the form of its case.

In the *Phryganæidæ* the case is made of pieces of leaves or stems placed side by side more or less spirally round the case.

The *Limnophilidæ* (Fig. 94) may use sticks placed transversely on the case, and often have a partiality for the shells of small molluscs, so that the case may be composed wholly or partly of these. Others again make cases of sand; one, *Limnophilus vittatus*, constructing a curved cylindrical tube of fine sand grains. One genus, *Enoicyla*, lives on land among moss. It may also be mentioned here that in this genus the female is wingless. In another genus of Limnophilids, namely *Apatania*, no male has as yet been found.

Fig. 94.—Larva of *Limnophilus* sp. in case. (× 2.)

The *Sericostomatidæ* make cylindrical cases of small stones or sand. They live almost entirely in running water. *Helicopsyche* makes a spiral case of sand of the same shape as a snail's shell (*Helix*).

In *Leptoceridæ* the case is of fine sand or leaf particles, curved, and cylindrical or tapering. A similar case is made by the *Odontoceridæ*. Many of the *Leptoceridæ* swim with their legs projecting out of the case.

Molanna constructs a very characteristic tube of sand with lateral projections so that the whole is shield-shaped.

The case of Hydropsychids is a very loose structure of stones or sand attached to stones, etc. Sometimes the larvæ are gregarious and live several in one habitation. Many make silk nets to ensnare other insects, and are carnivorous.

Polycentropus lives in rapid streams and is covered in debris. The larva is without gills, but in the pupa gills are present.

The *Rhyacophilidæ* live in very rapid streams and make loose cases of small stones, generally attached to some support. The pupa lies in a brown cocoon within the case and not, as in the other families, free in the case.

The *Hydroptilidæ* are small species resembling Tineid moths, with fringed wings. The larvæ have no respiratory filaments and construct cases of silk slit open at both ends, upon which small foreign bodies are placed. The whole case is compact and rather oval in shape. When about to pupate the case is fixed by silk threads to a support.

The pupa of all caddis-flies is a *pupa libera*. When about to emerge it cuts through the case with its pupal mandibles and then swims, using its legs, to a plant stem up which it climbs. On gaining the surface the imago is disclosed.

There is one brood per annum. Winter is passed as a larva.

Many specialized Hymenopterous parasites attack both eggs and larvæ of caddis-flies. Carnivorous insects and fishes relish the larvæ.

The order has been monographed by Ulmer in *Gen. Ins.* Fasc. 60 (1907). For references to larval habits MacLachlan (1874-80), Ulmer (1908–1914), Döhler (1920) and Rousseau (1921) should be consulted.

We have about two hundred British species of *Trichoptera*. These have been described at various times by MacLachlan and Morton. For a concise account of the European species see *Die Süss-wasserfauna Deutschlands*, 1909.

Theobald (Rep. 1894 and Rep. 1905–6) has recorded the larva of *Limnophilus flavicornis* F., as a pest in watercress beds in England.

MECOPTERA. Scorpion-flies

Head drawn downwards into a beak with extended clypeus and genæ.

The order will be treated in the present account as a whole. Five families are recognized: *Bittacidæ*, *Boreidæ*, *Panorpidæ*, *Notiothaumidæ*, and *Meropidæ*.

These insects are found in all parts of the world. They may be at once recognized by the beak, at the end of which are the mouth-parts. The legs are long, adapted for clinging or running. Coloration brown, the wings being marked with black as a rule, but some tropical species tend to warning coloration. A malodorous liquid may be secreted from the tip of the abdomen. *Bittacus* (Plate II, Fig. 5) resembles a Tipulid fly, *Boreus* (Plate II, Fig. 3) is wingless. The male sex is furnished with distinct genitalia, and in *Panorpidæ* the last three segments of the body form a scorpion-like tail. The female (Plate II, Fig. 1) is provided with an ovipositor.

The head is of very distinct shape, owing to the curious beak, but in some genera this is short and not conspicuous. Antennæ are long and slender, compound eyes and ocelli are present (no ocelli in *Boreus*). The clypeus, genæ, and submentum are elongated to form the beak. The mouth-parts at the end of this beak are mandibulate and toothed, but in *Bittacus* the mandibles are more adapted for piercing than for biting. Maxillæ are long and hairy with a five-jointed palpus. The labium and its palpi are reduced. The prothorax is short. Legs are long, with two tarsal claws, adapted for walking, clinging or hanging. There are two pairs of equal, membranous, many-veined wings which are commonly marked with dark blotches (Plate II, Fig. 1). Usually the venation is fairly open with a preponderance of longitudinal veins as in *Panorpa*, but in *Chorista* there are considerably more cross veins and the wings of *Notiothauma* are densely reticulate. In *Boreus* (Plate II, Fig. 3) the wings are reduced to mere rudiments. The abdomen is composed of ten segments. The female has an

ovipositor, the male, upturned swollen claspers. There are two thoracic and eight abdominal spiracles.

The alimentary canal is simple. There is a distinct proventriculus or gizzard, lined with chitinous setæ. Six Malpighian tubes are present; salivary glands are small.

The larvæ (Plate II, Figs. 2, 3) resemble those of *Lepidoptera*. They have large heads with simple eyes and short antennæ. Mandibles, maxillæ with palpi, and labium with labial palpi are present. There are three pairs of small thoracic legs and the first eight abdominal segments carry each a pair of simple prolegs. The back is covered with spines. The larva of *Boreus* (Plate II, Fig. 4) differs from that of other *Mecoptera* in having no abdominal prolegs, except perhaps in the first instar, and in the absence of spines on the back.

The life-history of *Panorpa* is as follows: Eggs, which are relatively large, oval, and creamy white in colour, are laid in clusters in the soil. They hatch in eight days, as a general rule. The larva (Plate II, Fig. 2) is not very active, but can move fairly rapidly in the U-shaped burrow which it makes just under the surface of the ground. Its food consists of animal matter. In captivity larvæ may be easily reared on meat or dead flies. After seven moults the larva makes a cell in the earth and here pupates. The imagines are found in damp shady places and are carnivorous, but probably only attack disabled insects. There are two broods in the year; winter is passed as a larva.

Bittacus (Plate II, Fig. 5) has a similar life-history; but the adult preys on living insects, which it catches in its long legs.

Boreus (Plate II. Fig. 3) appears in winter. The female lays her eggs in moss, and the larvæ (Plate II, Fig. 4) feed entirely on the bases of the moss plants. They are creamy white in colour and resemble weevil larvæ, but for the presence of six thoracic legs. Spring and summer are passed as a larva and in autumn pupation takes place. The imagines appear in early winter and also feed on moss, thus making an exception to the rest of the *Mecoptera*, which are wholly carnivorous.

Boreus has at least one Hymenopterous parasite, and birds feed on the larvæ. *Panorpa* is probably to a certain extent protected by its formidable appearance and nauseous secretion.

The *Mecoptera* have been monographed by Petersen in *Coll. Zool. Selys*, Fasc. V, 1921.

There are three British species of *Panorpa*, *P. communis*, *P. germanica* and *P. cognata*. *Boreus hyemalis* is also found in Britain : see MacLachlan (1868).

No economic importance can be attached to this order.

LEPIDOPTERA

Two pairs of wings, large and nearly equal in size, with not more than fifteen nervures and four cross-nervures on each ; the body and wings densely clothed in scales ; antennæ of varied form, but usually simple and prominent ; mandibles absent, except in Micropterygidæ, the maxillæ formed into a long tubular proboscis, which is coiled up when not in use and protected by the labial palps. Metamorphosis complete ; the larva with biting mouth-parts and from two to five pairs of sucker feet ; larva herbivorous as a rule, living openly on the food-plant ; pupa obtect, with or without a silken cocoon.

Lepidoptera are easily recognizable in the larval, pupal and imaginal stages. Although the size and colour are very variable, the structure throughout the group is exceedingly uniform.

The eggs are of three main types, those of the butterflies being usually upright and somewhat barrel-shaped (Fig. 105), those of the large moths rounded and slightly flattened (Fig. 117), and those of the small moths flat and scale-like (Fig. 133). These distinctions are not, however, very reliable, as many of the butterflies have eggs which more closely approach the moth type.

The larvæ of Lepidoptera, usually termed caterpillars, are very uniform. The head is distinct and thickly chitinized. The eyes are very imperfect, consisting merely of up to six ocelli, situated on each side of the lower part of the head. The mandibles are the most important feature of the mouth-parts ; labium, labrum and maxillæ are present, but the last named are very small. The spinneret, by means of which the silk is exuded, is prominently placed on the labium. Antennæ are present, but are very inconspicuous. Behind the head there is a small chitinized plate, and minute chitinized tubercles, each bearing a hair, are found on every segment throughout the length of the body. The body, not including the head, consists of thirteen segments, of which the first

three, the thoracic segments, bear the true legs. The remaining ten segments constitute the abdomen, and in the normal larva a pair of sucker-feet is present on each segment from the third to the sixth, and another pair, distinguished as anal claspers, on the last.

The true legs and the sucker-feet are quite different structures, and must not be confused. The former are jointed, and give rise to the legs of the imago: they are always six in number. The sucker feet, however, are unjointed; they are usually provided with hooks, vary in number and disappear during

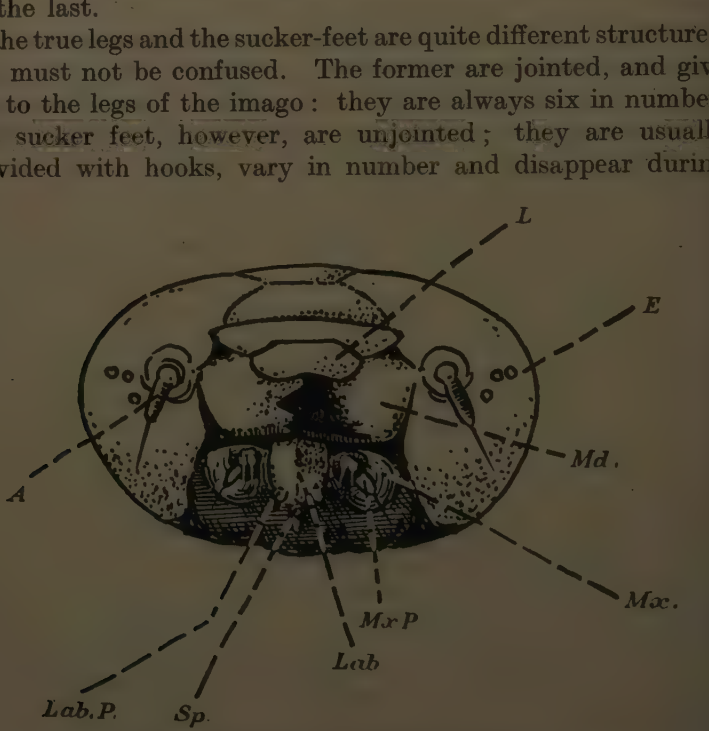


FIG. 95.—Head of Caterpillar from below.

A = antenna. *E* = simple eyes. *L* = labrum. *Md* = mandible. *Mx* = maxilla. *MxP.* = maxillary palp. *Lab* = labium. *Lap.P.* = labial palp. *Sp.* = spinneret.

metamorphosis. There are nine spiracles on each side of the larva: a pair on the first thoracic and a pair on each of the first eight abdominal segments.

The internal structure of the larva is simple, the larger part of the body cavity being occupied by the enormous stomach. Three sets of glands open into the mouth: the two mandibular glands, which open one at the base of each mandible; the silk glands, of which the ducts fuse and open to the exterior as the spinneret; and the glands of Filippi, which open into the ducts of the silk glands. The nervous

system is simple, consisting of a frontal ganglion, supra- and infra-œsophageal ganglia, and a ventral chain of eleven ganglia. External sexual organs are not present in the larva, but rudimentary testes or ovaries are found. During its growth the larva usually undergoes five to six moults. It is often very difficult to distinguish the family to which a larva belongs, but the following characters are fairly definite:

Larvæ with the sucker feet absent are *Limacodidæ*. Larvæ with the hooks on the sucker feet arranged in a circle, are

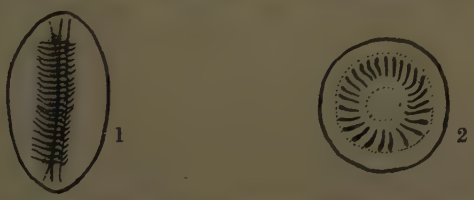


FIG. 96.—Diagram showing arrangement of hooks on sucker feet of Lepidoptera.
1. Sphingid. 2. Tortricid.

Tortricidæ, *Pyralidæ* or *Tineidæ*. *Tortricidæ* usually have the chitinized plate behind the head in the form of a bar.

Case-bearing larvæ are *Tineidæ* or *Psychidæ*; these may be distinguished by their size and the arrangement of hooks on the sucker feet.

Larvæ with a retractile Y-shaped process on the thorax are *Papilionidæ* (Fig. 104).

Many larvæ of *Nymphalidæ* have numerous rows of spiny processes on the body (Fig. 108).

Slug-like caterpillars with short dense hair are *Lycænidæ* (Fig. 110).

Smooth caterpillars with a distinct neck are *Hesperiidæ* (Fig. 111).

Smooth larvæ with only a few short hairs are *Pieridæ* (Fig. 106) or *Noctuidæ* (Fig. 114), if cryptically coloured, usually the latter.

Uniformly hairy larvæ are *Arctiidæ* (Fig. 112) or *Euptero-idæ*.

Hairy larvæ with upright "shaving-brush" tufts are *Lymantriidæ* (Fig. 118), with lateral tufts *Lasiocampidæ* (Fig. 131).

Large caterpillars with processes bearing hairs are *Saturniidæ* (Fig. 126).

Large caterpillars with the anterior segments enlarged and an anal process are *Sphingidæ* (Fig. 120).

Larvæ with the sucker feet reduced to three or four pairs (Semi-loopers) are *Noctuidæ* (Fig. 115).

Larvæ with the sucker feet reduced to two pairs (Loopers) are *Geometridæ* (Figs. 124, 125).

The pupa is usually brown, but in the case of some butterflies is of bright metallic colours. It is frequently enclosed in a cocoon, which is of silk, with or without the incorporation of surrounding material. The pupa is strongly chitinized, as resistance to unfavourable weather conditions is of the first importance, the greater part of the year being frequently spent in this stage. With the exception of some of the abdominal segments, the pupa is incapable of movement, all the appendages being firmly glued down to the body (Fig. 121). At the end of the body there is usually a curious process called the cremaster. This is often provided with hooks which secure the pupa in the cocoon, or to a pad of silk placed on the foodplant.

Fig. 97.—Head of Butterfly.
a = antenna. *e* = eye. *mp* = maxillary palp. *p* = proboscis.

The imagines of Lepidoptera, like the larvæ, are very uniform in structure. The most noticeable features of the head are the large compound eyes, the antennæ, and the labial palps, which latter conceal the coiled-up proboscis. The antennæ are very prominent, except in the *Hepialidæ*, and in some cases are of very complex structure. They frequently differ in the sexes. The most important features of the mouth-parts are the maxillæ, forming a tubular proboscis, and the labial palps, which protect the proboscis when it is not in use. The proboscis, especially in the *Sphingidæ*, is

often very large, in some cases attaining a length of ten inches. The other mouth-parts are absent or very small, and are unimportant. In the thorax, the mesothorax is the most important division, the pro- and meta-thoraces being much reduced. Each segment bears a pair of legs, and the meso- and meta-thorax a pair of wings. The legs consist normally

FIG. 98.—Venation of Butterfly named after Hampson.

C = costal shoulder.

of a coxa, a trochanter, a femur, and a five-jointed tarsus; but in some families of the *Rhopalocera* the fore-legs are reduced. The wings are large, and in most cases both pairs are functional in flight, the exception being some members of the family *Papilionidæ*, in which the fore-wings only are used, the hind-wings being trailed. Three devices are found for locking the front and hind wings:—

A. The front wing overlaps the expanded basal area of the

anterior edge of the hind-wing. This is found in all the butterflies and in a number of moths.

B. Frenulum and retinaculum. The frenulum, which is a stiff bristle on the upper surface of the anterior margin of the hind-wing, engages in the retinaculum, which is a catch formed

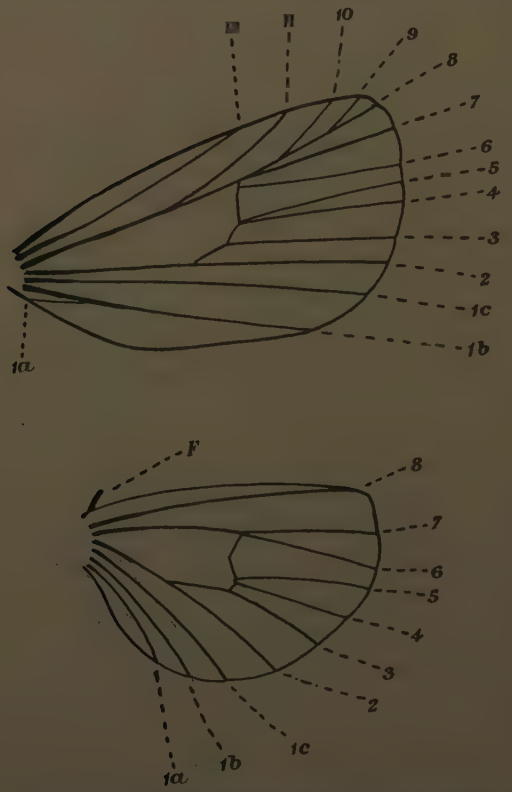


FIG. 99.—Venation of Moth named after Hampson.

F = frenulum.

of thick scales on the under-side of the fore-wing. This is found in the majority of moths.

C. Jugum. This is a lobe extending from the fore-wing and passing under the hind-wing, holding the latter between itself and the fore-wing. This is found in *Hepialidæ* and *Micropterygidæ* only.

The venation of the wings is important, as on it the classifica-

tion of the Heterocera largely depends. In the typical fore-wing there are twelve veins: the internal nervure with three branches (1*a*, 1*b*, and 1*c*), the median nervure with two branches (2, 3), the radial with three branches (4, 5, and 6), the subcostal with five branches (7, 8, 9, 10, and 11), and the costal nervure

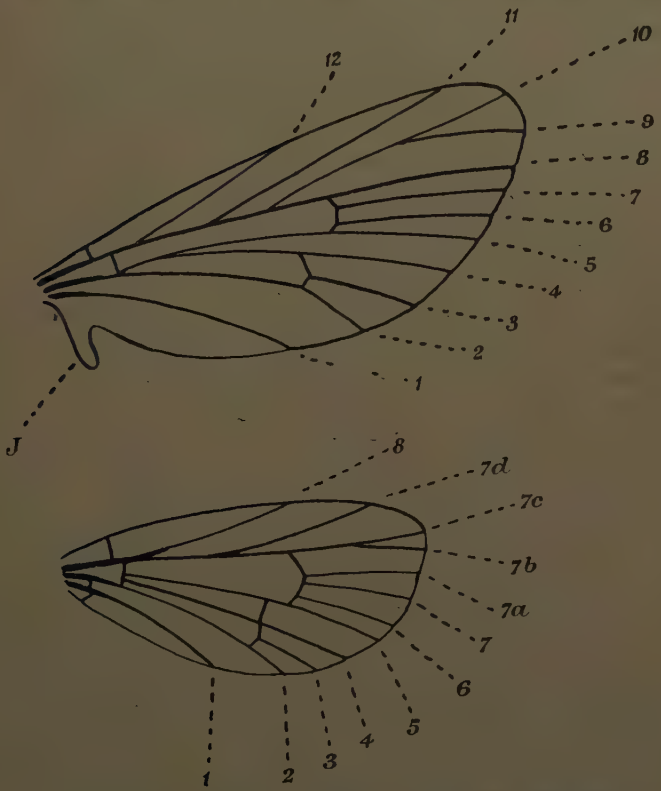


FIG. 100.—Venation of Hepialid named after Hampson.
J = jugum.

(12). The hind-wing has typically eight nervures, four of the subcostals being absent.

The internal anatomy of Lepidoptera is not very complex. The only peculiarity of the alimentary canal is a large pouch, which opens just behind the crop. This is called the "sucking stomach," but its function is doubtful. The nervous system is normal, consisting of a small frontal ganglion; supra- and

infra-œsophageal ganglia, which are united and pierced by the œsophagus; and a ventral chain, comprising three thoracic and four abdominal ganglia. The male sexual organs do not exhibit any great peculiarity: they consist of a pair of testes whose vasa deferentia unite to form a long ejaculatory duct. The female organs, however, are more complicated. There is a pair of ovaries, whose ducts unite to form a single oviduct, which opens at the apex of the abdomen; and, in addition, a bursa copulatrix, which opens on the ventral plate of the

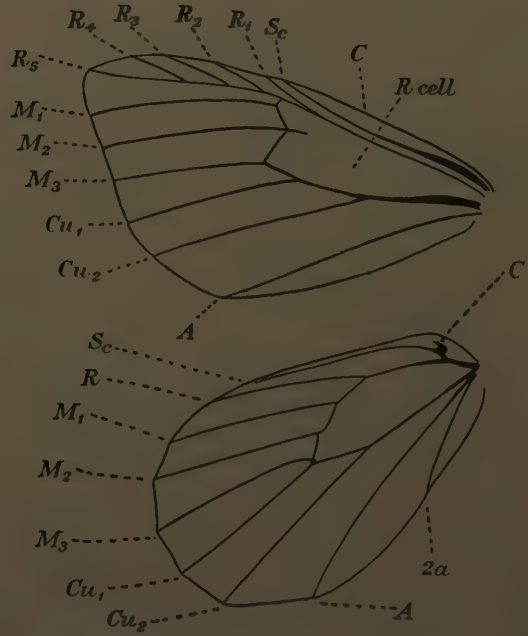


FIG. 101.—Venation of Butterfly named after Comstock and Needham.

eighth abdominal segment. Connecting the bursa copulatrix with the oviduct is a tube, on which is situated the spermotheca. A pair of accessory glands and also an unpaired gland open into the oviduct. In *Micropteryx* and some others there is a single genital aperture, not a double one.

The colours of *Lepidoptera* are very varied, and in the order we can find examples of every device adopted by insects to protect themselves from their enemies.

Broadly speaking, the colours adopted may be placed in the three following classes :—

1. Hiding colours.
2. Warning colours.
3. Frightening colours.

The "Hiding" colours may be divided into two groups, of which the first is composed of those colours known as "Cryptic," i.e. colours which bear a general resemblance to their surroundings. These are adopted by most night-flying moths and by many larvæ. They are usually dull colours and are broken up by irregular bands or blotches. The second group are those colours which give the insect a resemblance to some particular object; they are often correlated with a peculiar shape or attitude. Examples of this are found in most *Geometrid* larvæ, which, while at rest, resemble dead twigs; in the Buff-tip moth, which resembles a broken-off twig; and in many small moths, which rest on leaves, etc., with outspread wings, and exactly resemble the excrement of birds.

In *Warning* colours we again find more than one type. True warning coloration is simple: the insect is distasteful, and displays bright contrasting colours, usually red or yellow and black, to advertise the fact. *False warning* colours are similar colours adopted by an insect which does not taste unpleasant, but looks as if it does. Closely allied to this is *mimicry*, which is the imitation of one insect by another. Bates, who originally drew attention to the phenomenon, assumed that the mimic was always edible and the mimicked species inedible (Batesian mimicry). But it has since been discovered that many of the mimics are themselves distasteful, and a new theory, that distasteful insects tend to become of similar appearance (Mullerian mimicry), has been propounded. Examples of mimicry are found in many families, particularly in *Nymphalidæ*, where females of many species mimic other species of the same or different families, and in the *Syntomidæ*, many members of which closely imitate *Hymenoptera*.

"Frightening Colours" is the term applied to those colours, often used in conjunction with other devices, which are supposed to scare away enemies of the insect. One example of this is the Peacock butterfly, which, when

approached, suddenly opens its wings and displays four glaring eyespots. Other examples are the larvæ of *Papilionidæ*, which extrude a brightly coloured process from the front portion of the body, and the *Sphingid* larvæ, most of which possess eyespots, and which in a few cases emit a hissing sound when alarmed.

Most of the theories regarding insect colours must be accepted with caution, as there are many objections which have yet to be removed. For instance, mimicry and false warning colours would in many cases seem to defeat their own end. If, as frequently happens, the mimics outnumber the mimicked, or the possessors of false warning colours are more numerous than the genuinely distasteful, then surely birds and other enemies would associate edibility, and not distastefulness, with those particular colours. Again, in the case of frightening colours, we are too apt to imagine that what would, if magnified, certainly frighten us, must necessarily be alarming to a bird. Until these and similar points are cleared up, it must be admitted that the question of the colours of insects is very imperfectly understood.

The principal natural enemies of *Lepidoptera* are birds; insectivorous mammals, such as bats, squirrels, and monkeys; internal parasites, of the orders *Hymenoptera* and *Diptera*; and certain predaceous insects, particularly the fossorial wasps.

Birds destroy large numbers of the imagines and an enormous number of larvæ. It is an interesting fact that birds have great difficulty in picking larvæ off the foliage of plants, as in most cases the leaves or twigs on which the larvæ feed are not strong enough to allow the bird to settle. It is when the larvæ leave the foliage and crawl down the stems to pupate that the greatest destruction takes place. Another point worthy of mention is that when, for any reason, caterpillars suddenly become very numerous, large numbers of birds that are not usually insectivorous will attack them, and will materially assist in reducing their numbers.

Hymenopterous and Dipterous parasites are a very large factor in the natural control of *Lepidoptera*. The larvæ are most frequently attacked, the female parasite laying one or more eggs in the partially grown caterpillar. These eggs hatch to small larvæ, which feed inside the caterpillar: at the pupation stage the caterpillar is practically eaten out,

and dies, the parasite pupating inside or outside the dead shell. The eggs of *Lepidoptera* are also frequently attacked, four or more tiny parasites sometimes undergoing their development in one egg. Practically every family of *Lepidoptera* is attacked to a greater or less extent by these parasites. The principal families concerned are *Ichneumonidæ* and *Braconidæ* (*Hymenoptera*) and *Tachinidæ* (*Diptera*), which parasitize caterpillars; and *Chalcidæ* and *Proctotrypidæ* (*Hymenoptera*), which are egg-parasites.

The food of the adult insect consists almost entirely of nectar from the honey glands of flowers. Sap from a wounded tree is also very attractive to some *Lepidoptera*, especially *Nymphalidæ* and *Noctuidæ*, and a few species are attracted by carrion: *Ophideres* and some others puncture fruit, especially oranges.

The larvæ in the main are herbivorous, mostly feeding on the foliage of plants. A few bore into stems; others into fruit, where the seeds are usually consumed. Very few lepidopterous larvæ are carnivorous; some, however, attack scale insects and aphides, and a few *Lycænids* consume ant larvæ and mealy-bugs. Some *Tineids* eat cloth, others of the same family cork, and one consumes the whitewash on house walls. Some *Pyralidæ* feed on flour, biscuits, etc.

Silk. Silk is the thread produced by many insects from the salivary glands. It is formed in the glands as a viscous gummy fluid, but on exposure to the air rapidly dries to a strong thread. It is used by the insect for a variety of purposes, but in *Lepidoptera* its principal use is the formation of the cocoon. Practically all the larvæ of *Lepidoptera* produce silk in greater or less quantity, but the production of only a few species has any commercial value, the following being the most important:—

1. *Bombycidæ*. *Bombyx mori*, the mulberry silkworm. Domesticated in India, China, Japan, and Europe.
2. *Saturniidæ*.
   - (i) *Attacus ricini*, Eri Silk. Domesticated in India. The silk can only be spun.
   - (ii) *Antheræa paphia*. Tussar Silk. Wild in India, China, and Japan.
   - (iii) *A. assama*. Muga Silk. Semi-domesticated in Bengal and Assam.

(iv) *Antheræa pernyi*. Shantung Silk, occurring in China.

(v) *Antheræa yama-mai* from Japan.

3. *Eupterotidæ*. Species of the genus *Anaphe* from tropical Africa.

Bombyx mori, the mulberry silk worm, supplies the bulk of the world's silk. It is probably indigenous to India or China, where it has been domesticated for centuries, but it is nowhere now found wild. It was introduced into Europe in the sixth century, and has been cultivated there ever since, principally in Southern France and in Italy. There are several races of *B. mori*, some univoltine, i.e. with only one brood during the year, such as the European race; others, such as the Indian races, multivoltine or many-brooded. Mulberry is the exclusive food-plant: in Europe the White Mulberry, *Morus alba*, gives the best results.

Bombyx mori is a pale grey moth, measuring about one and a half inches across the wings. It is very feeble, and does not take any food, the proboscis being absent. Coupling takes place immediately after emergence, and the moths live for a few days only.

The eggs, which are pale yellow, are laid, in the case of the univoltine species, in August or September: about 400 eggs are laid by one female. The eggs are termed "seed," and are sold by weight; one ounce of "seed" contains from 30,000 to 55,000 eggs.

As a rule the females deposit their eggs on cards, which are then put away for hibernation, great care being taken to maintain a uniform temperature during the winter. In May, when the eggs are ready to hatch, they are placed in trays, and covered with mulberry leaves. The space allowed for one ounce of seed is as follows, the figures in this and subsequent tables being taken from Lefroy's Report on Silk in India:—

At hatching . . .	·3	square metres.
After 1st moult . .	1	,, ,,
,, 2nd ,, . .	3	,, ,,
,, 3rd ,, . .	9	,, ,,
,, 4th ,, . .	22	,, ,,
Before spinning . .	60	,, ,,

The caterpillars are grey or grey and black in colour, and smooth, with a hornlike process on the dorsal plate of the last segment. The mulberry leaves are usually cut up before being supplied to the larvæ. There are four moults, and the larval stage in Europe occupies about a month. Altogether about 1,398 lb. of leaves are supplied to the larvæ from 1 oz. of seed: this produces about 120 lb. of green cocoons (i.e. cocoons + living pupæ). About 606 lb. of food is untouched, and 160 lb. of excrement is produced. The following table gives the weights of silkworms at various stages:—

36,000 eggs	=	25 grammes seed.	
At hatching	weigh	18 grammes.	
After 1st moult	,,	255	,,
,, 2nd ,,	,,	1,598	,,
,, 3rd ,,	,,	6,800	,,
,, 4th ,,	,,	27,676	,,
At greatest size	,,	161,500	,,
At maturity	,,	131,920	,,
As cocoons	,,	76,250	,,
Chrysalides alone	,,	66,300	,,
Moths (50 per cent. each sex)	,,	39,685	,,

When the worms are full fed, loose twigs, on which the cocoons are spun, are placed above the trays. The cocoons are about the size of a pigeon's egg: those of the males are smaller than those of the females. About 500 cocoons weigh one kilogram. When the cocoons are finished, certain are selected for seed, and the remainder, after grading into qualities, are killed by placing in dry, hot air for about ten minutes, preparatory to reeling. In reeling, the cocoons are placed in hot water, in order to loosen the gummy threads; after the removal of the outer layer, the threads from several cocoons are taken, mechanically twisted, and reeled off on a slow-moving bobbin. About 300 yards of thread is taken from each cocoon. This raw silk is frequently woven without further preparation; it is, however, often thickened by the further twisting of several threads together, and in many cases dyed, before weaving. The waste silk is now combed and spun in a similar manner to wool.

In addition to silk, the silk glands of *Bombyx* supply what is known as silkworm gut. This is a very strong material, principally used for fishing tackle. When ready to spin, the worms are placed in vinegar, where they are allowed to remain for about fourteen hours. The silk glands are then extracted and drawn out to a length of from one to three feet, stretched on a board, and dried in the sun. In China, silkworm gut is made from the glands of another species, *Saturnia* (*Eriogyna*) *pyretorum*, of the family *Saturniidæ*.

Silkworms are liable to a number of diseases, of which the most important is Pebrine. This is caused by a protozoon, and is infectious and contagious, and can also be passed on from generation to generation through the female. At one time the disease almost wiped out silk cultivation in Europe, but now it is kept under by Pasteur's method of segregation of the females. Each fertilized female lays its eggs in a separate cell; the body of the moth is then pounded up in water, and microscopically examined for the disease: if it is present, the eggs are destroyed.

Eri Silk: *Attacus ricini.*

This species is cultivated in Eastern Bengal and in Assam, mainly for local use. It is wholly domesticated, but a very closely allied species, *A. cynthia*, is found wild in many districts: probably this is frequently crossed with *A. ricini*. The larvæ will feed on a variety of plants, but the Castor-oil plant is the one most frequently used. Rearing is done indoors, in trays, in a similar manner to *Bombyx mori*. The silk is white or brown, and can be spun only, the moths usually being allowed to emerge. The cocoons are frequently sold with the pupa case inside, in which case they are often weighted with mud or stones. In other cases they are cleaned, by turning them inside-out by machinery. Eri silk is largely used in India, but very little is exported to Europe.

Tussar Silk: *Antheræa paphia.*

This is a wild species that feeds on various forest trees. There are several races, which are one, two, or three brooded. There are two sources of cocoons: wild cocoons, which are collected in areas where the moth is abundant; and cocoons

obtained by placing larvæ on selected trees. The larvæ in the second case are hatched from seed which is usually the product of wild moths: seed from reared moths being poor in quality and uncertain in supply. The silk is coarse, very strong, and of a dark buff colour. It is reeled, the pupæ being stifled. Tussar silk is woven in India mainly for local use; for export it cannot compete in price with the Chinese Shangtung.

Muga Silk: *Antheræa assama.*

This is a semi-domesticated species found in Assam, feeding principally on Laurels. The eggs are laid on special grass rods, which are then hung up indoors until the worms hatch. When this takes place, the rods are hung on a tree, and the worms crawl up and feed on the foliage. After stripping the tree, the caterpillars crawl down the stem and collect on triangular mats which are placed on the trunk in readiness: the mats are then taken to another tree and hung on it. When full grown the larvæ crawl down the tree, and are collected and placed in branches of dry leaves, where they pupate. Seed cocoons are carefully selected, and the remainder are stifled and reeled. All the silk is reeled locally, and the greater part is woven locally, but a small quantity is exported to other parts of India, where it is valued on account of its beautiful dull bronze colour.

Shantung Silk or Chinese Tussar: *Antheræa perneyi.*

This species is very extensively reared in China. It is bivoltine, and is found both wild and semi-domesticated in many districts. It is usually reared indoors, though occasionally upon dwarf oaks in the open air. Oak is the exclusive food-plant used. Two crops of silk are obtained annually, one in the spring and one in the autumn: the latter is heavier, but poorer in quality. Shantung silk is pale buff in colour, and is very largely exported.

Antheræa yama-mai.

This is the corresponding Japanese species to *A. perneyi*, and like it feeds exclusively upon Oak, and is reared in a similar manner. It is, however, only single-brooded, and is now

being largely replaced by the Chinese species. *A. yama-mai* yields silk of a beautiful pale-green colour, which was formerly strictly reserved for the Royal House of Japan.

Species of *Anaphe*.

Various species of this genus, which occur in tropical Africa, yield silk which is used commercially to a small extent. The larvæ spin colonial cocoons which are covered with a common envelope. The silk, which is grey in colour, is of little value. The envelope only is used, and the threads not being continuous, spinning only is possible : efforts are being made to extend the production of these species.

Very few *Lepidoptera* are beneficial to man ; these are :

(*a*) Those that produce commercial silk.

(*b*) Certain carnivorous larvæ, which may to some extent check the ravages of scale-insects, etc.

(*c*) To a very slight extent, the *Morphinæ* of S. America, whose wings are used for ornamenting jewellery.

The harmful members of the group may be summarized as follows :—

(*a*) *Leaf-eating Caterpillars.* The ordinary type of lepidopterous larva, which lives openly on one particular food-plant. These pests occur in nearly every family of the order.

(*b*) *Surface Caterpillars.* Known as "Cutworms" in America, these are Noctuid larvæ principally of the genera *Agrotis* and *Euxoa*. They live on or just under the surface of the soil, feeding at night on young shoots of plants, which they bite off at ground level.

(*c*) *Army Worms.* Noctuid larvæ which, because of food shortage, or for some other reason, become gregarious and migrate, consuming everything in their path. The best-known example is *Leucania unipuncta*.

(*d*) *Borers.* The principal pests in this class are those that attack sugar cane, being members of the families *Noctuidæ*, *Pyralidæ*, *Tortricidæ*, and *Castniidæ*. Other boring larvæ are *Sesiidæ* on Currant, Gooseberry, etc., and *Cossidæ* in large timber.

(*e*) *Bollworms.* Larvæ which bore into the boll of cotton and consume the seeds. They constitute a very serious pest, the

worst offender being *Gelechia gossypiella* of the family *Tineidæ*. Others belong to the *Noctuidæ*, e.g. *Earias fabia* in India and *E. insulana* in Egypt.

(*f*) *Fruit Borers.* Larvæ which tunnel into fruit, nuts, etc. These are principally larvæ of the family *Tortricidæ*, the best known being the Codlin Moth, *Cydia pomonella*, which attacks apples and pears.

(*g*) *Minor Household Pests.* Among these we may include the flour moth, *Ephestia kühniella*, a member of the family

FIG. 102.—Antennæ.

1. Pierid Butterfly. 2. Hesperiid Butterfly. 3. Sphingid Moth. 4. Zygænid Moth.

Pyralidæ, which is found in flour mills and Army biscuits; the clothes moths, *Trichophaga tapetzella* and others, of the family *Tineidæ*; and *Oinophila v-flavum*, belonging to the same family, which attacks the corks of wine bottles, and has recently been reported as injuring the corks in breweries and factories.

The classification adopted here is that of Hampson, with a few slight differences. The suborders *Rhopalocera* and *Heterocera* have been retained, and the families of the former arranged in the order adopted by South. In some cases, where the family name has been changed, the older and better-known name is

retained. The characters for the families given here are those in Hampson's Catalogue.

There is an enormous amount of literature relating to *Lepidoptera*, and nearly every country has its own textbooks and lists of species.

The more important general catalogues are the following :— (1) Staudinger & Rebel. *Catalogue of Palæarctic Lepidoptera* 1901. (2) Dyar. *Lisi of N. American Lepidoptera*, 1902. (3) *Lepidopterorum Catalogus*, edited by H. Wagner (in course of production). (4) Hampson. *Catalogue of Lepidoptera Phalænæ*, 1898-1920 [covering *Syntomidæ*, *Arctiidæ*, *Agaristidæ*, and *Noctuidæ*].

For the *Lepidoptera* of Great Britain, the butterflies and larger moths are dealt with by South (1906–1909) and the *Micro-lepidoptera* by Meyrick (1895).

Sub-Order I. *RHOPALOCERA*. Butterflies.

Antennæ clubbed or thickened just before the tip ; frenulum absent ; usually day-flying. Pupa as a rule without a cocoon.

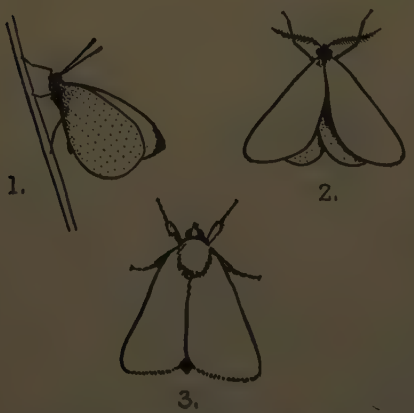


FIG. 103.—Diagram showing the Resting Attitudes of *Lepidoptera*. The Hind-wings are shaded.

1. Butterfly. 2. Geometrid Moth. 3. Noctuid Moth.

There is usually no difficulty in recognizing butterflies, though definite distinctive characters are not easy to give. The main distinction is the absence of the frenulum, the fore- and hind-wings being locked by means of a shoulder on the anterior edge of the hind-wing, as already described. This character, coupled with the form of the antennæ, should be sufficient for the recognition of doubtful cases. A useful field character is the position in which the wings are held when at rest. In butterflies, with the exception of the *Hes-*

peridæ, they are held vertically above the body, while in most moths they are folded flat across the body, the hind-wings being completely concealed. In the Skippers the wings are held partially open at an angle from the body.

The *Rhopalocera* have been more extensively studied than any other group of insects, and there is an abundance of literature. The more important general catalogues have been previously referred to; any volumes of *Genera Insectorum* that exist are mentioned under the families that they describe.

About 15,000 species of butterflies have been recorded, of which sixty-eight are British.

Papilionidæ.

Swallowtails.

All the legs fully developed; claws simple without empodium; precostal nervure absent in the hind-wings. Larvæ with retractile thoracic process.

Papilionids are all large butterflies, particularly the genus *Ornithoptera*. In most cases the colours are conspicuous, yellow and black being predominant. Very frequently the hind-wings are produced into a tail. In a number of cases the flight is peculiar, the fore-wings only being used, the hind-wings being trailed and taking no part in the function.

Fig. 104.—Larva of Papilionid (*Papilio Machaon*) (nat. size).
o = osmeterium.

The eggs are laid singly on the food-plant. They are barrel-shaped and ribbed, with a micropyle at the top. The larvæ of this family have a remarkable process on the thorax, known as the osmeterium: it is Y-shaped and provided with a stink gland, and is extruded when the insect is alarmed. In most cases the pupa is fixed to the food-plant by the tail, and supported by a girdle of silk round the middle, but in the genus *Thais* the girdle is absent, and the

pupa is supported by a thread at the top of the head. Larvæ of the genus *Parnassius* pupate on the ground, and form a slight silken cocoon.

Distribution is mainly tropical, but a considerable number of species are found in temperate regions. About 700 species have been recorded, only one of which is British.

In many cases sex recognition is difficult, but in others, particularly in the genus *Ornithoptera*, the females are much larger, and, as a rule, of duller coloration than the males.

Hibernation, when it occurs, is as a pupa.

Wherever Citrus is grown a species of *Papilio* attacks the young leaves, often causing serious damage. *Papilio demoleus*, occurring in India and the East, is one of the best known.

Two fascicules of *Genera Insectorum* deal with groups of this family, namely, No. 4 (1902) by Wytsmann and No. 6 (1902) by Rippon.

Pieridæ.

Whites and Sulphurs.

All the legs fully developed. The claws of all the legs bifid or toothed, and an empodium is present. The precostal nervure is present in the hind-wings.

The Pierids are medium-sized to large insects. They usually exhibit either white or yellow as the predominant colour, but red and black coloration is common among tropical forms

Fig. 105.—Eggs of *Pieris rapæ*. (× 15.)

Fig. 106.—Pierid Larva (*Pieris brassicæ*). (× 2.)

The eggs, which are of the barrel-shaped form usual in butterflies, are laid singly or in batches on the foliage of the food-plant. In the case of the common Cabbage White, 60–100 eggs are laid in a batch. The larvæ are usually bare or covered merely

with fine short hairs: the young caterpillars of some species, however, have a number of forked setæ, each of which bears a minute drop of fluid. At this stage the larva is very inactive, and feeds very little. At the second moult these specialized setæ disappear: there is, as a rule, some change in colour, and the larva becomes much more active and voracious. The pupa, which is often of fantastic shape, is always fixed to some solid object by the tail, and suspended by a silken girdle round the middle.

Fig. 107.—Pupa of Pierid (*Pieris brassicæ*). Lateral view.

(After Hargreaves—simplified.)

The distribution of the family is world-wide: over 1,000 species have been described, of which ten are found in Britain.

Hibernation when it occurs is as a pupa. Many temperate species pass the greater part of the year in that stage, the Orange Tip, for example, spending nine or ten months as a chrysalis.

The sexes can be distinguished in some species by a considerable difference in colour, but no general rule for the family can be laid down.

A number of species of *Pieridæ* feed on cultivated crucifers, but do not constitute serious pests. *Pieris brassicæ*, which attacks cabbages in Britain, is a typical example.

Nymphalidæ.

The fore-legs in both sexes much reduced; their tarsi in the male of one joint and in the female of five joints, without claws in either case. The pupa usually suspended by the tail and hanging down freely.

The *Nymphalidæ* are very variable both in size and colour. Some of the most brilliantly coloured as well as some of the dingiest of butterflies are found in this family. The members of the South American sub-family *Brassolinæ* resemble moths in their habits, inasmuch that they rest during the day, flying only in the late afternoon and evening. The British species

of the genus *Pyrameis* are often found on the wing after dusk. The flight in some species is very powerful (e.g. the well-known migrant *P. cardui*) ; in others, particularly in the *Satyrinæ*, it is very feeble.

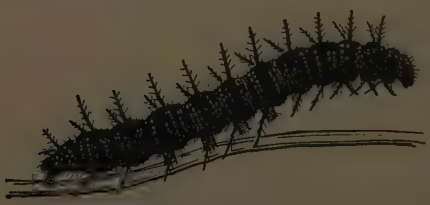


Fig. 108.—Larva of Nymphalid (*Vanessa io*) (nat. size).

Nymphalids constitute a large family with a world-wide distribution. Nearly 5,000 species have been described, of which thirty are British.

The eggs are laid either singly or in batches, and are usually affixed to the food-plant, though in the case of some of the grass-feeding species they are merely dropped among the grass stems. The larvæ differ largely in appearance, many being covered with long spines, while others are smooth. In some cases the extremity of the body is forked, and the larvæ of the genus *Apatura* have processes on the head. In some species the larvæ are gregarious. The pupæ of the Nymphalids are more elaborate than in other butterflies, being frequently adorned with curious processes. They are often of bright metallic colours. Normally they are suspended head-downwards by a series of hooks situate on the cremaster. In a few species of the sub-family *Satyrinæ*, however, the pupa is enclosed in a slight silken cocoon or in a cell just under the surface of the ground ; and occasionally in the same sub-family it is merely placed upright among grass stems without any attachment.

Fig. 109. — Pupa of Nymphalid (*Argynnis paphia*) (nat. size).
c = cremaster

Hibernation in this family usually takes place as a larva ; a few species hibernate as adults, but hibernation in the pupal stage is rare.

The sexes can be distinguished by the structure of the fore-legs : the tarsi in the male consisting of one joint and in the female of five joints.

Nymphalidæ are of very slight economic importance, a few species only being recorded as leaf-eating pests. *Acræa terpsichore*, which attacks sweet potato in Uganda, and *Vanessa c. album*, which attacks mulberry in Europe, will serve as examples.

The family is divided into the following sub-families, which are treated as separate families by some authorities :—

1. *Nymphalinæ*. This is a large sub-family with a world-wide distribution. The butterflies are as a rule brightly coloured on the upper side, but frequently dully or cryptically coloured underneath. The well-known dead-leaf butterflies belong to this group. One section of this group has been described by Stichel in *Genera Insectorum*, Fasc. 63 (1907), under the title *Dioninæ*.

2. *Danainæ*. These are large dully coloured butterflies, most common in the Eastern tropics.

3. *Ithomiinæ*. The members of this group are of small size, and vary considerably in colouring. In some forms large hyaline patches occur on the wings. The sub-family is confined to tropical America.

4. *Palæotropinæ*. This is a small group of moderate-sized black and white butterflies from the Austro-Malayan region.

5. *Morphinæ*. This is a small group confined to tropical America and the Eastern tropics. They are as a rule large butterflies with brilliant metallic-blue coloration and strong powers of flight. Two sections of the group (*Discophorinæ* and *Hyantinæ*) have been described in *Genera Insectorum*, Fasc. 31 and 39 (1905), by Stichel.

6. *Amathusiinæ*. This sub-family has been separated from the *Morphinæ*. It consists of a small number of species from the Eastern tropics, and has been described by Stichel in *Genera Insectorum*, Fasc. 36 (1906).

7. *Brassolinæ*. This is a small group of large brightly coloured insects from South America. They rest during the day, flying in the late afternoon and evening. The group is described by Stichel in *Genera Insectorum*, Fasc. 20 (1904).

8. *Heliconiinæ*. The members of this small South American sub-family are brightly coloured insects of rather small size. The wings are longer and narrower than is usual in Nymphalids.

The sub-family is described in *Genera Insectorum*, Fasc. 37 (1906), by Stichel.

9. *Acræinæ*. This is a small sub-family of dull-coloured butterflies of moderate size. Their distribution is mainly African. They are described by Jordan and Eltringham in *Genera Insectorum*, Fasc. 169 (1916).

10. *Satyrinæ*. The members of this group are the common Browns and Heaths, which are found all over the world. The butterflies are dull in colour and of moderate to small size. Their powers of flight are usually feeble.

Lycænidæ.

Fore-legs slightly reduced, their tarsi in the male consisting of one elongated joint with a single claw. The claws not toothed.

Lycænids are small to moderate-sized insects. The most common coloration is blue for the upper side and mottled grey for the under-side, though other colours are frequently found. Not infrequently appendages or tails are present on the hind-wings.

Fig. 110.—Larva of Lycænid (*Zephyrus betulæ*). (× 2.)

Lycænids are found all over the world. Upwards of 2,000 species have been recorded, of which eighteen are British.

The eggs are round and somewhat flattened, the diameter being greater than the height. They are laid singly and affixed to the food-plant. The larvæ are slug-like, being short and thickened in the centre, with the legs and sucker feet hidden beneath the body. The majority are herbivorous, but a few species are wholly or partly carnivorous, feeding on scale-insects, aphides, or ant larvæ. Those that consume ant larvæ usually possess glands in the posterior portion of the

body which yield a fluid of which the ants are fond. Some species (e.g. *Lycæna arion* in England and *L. alcon* in France), feed on foliage during the summer, and in winter enter ants' nests and feed on the larvæ and pupæ. *L. alcon* exhibits the further peculiarity of only passing through three larval instars, instead of the normal six. The pupæ of the Lycænids are short and thickened, usually dark brown in colour. They are normally suspended by the cremaster and supported by a silken girdle, but occasionally the girdle is absent.

Hibernation takes place usually as a larva, but in some cases the insects pass the winter in the egg or pupal stage.

The sexes can be distinguished by the tarsi of the fore-legs, which consist in the male of a single joint. In many cases the male is more brightly coloured than the female, but there are exceptions. In the case of the British species, *Zephyrus betulæ*, where the female possesses the brighter colours, it is interesting to note that in coupling the male is carried by the female, this being a reversal of the usual procedure.

The family has little importance economically, but one species, *Virachola isocrates*, is a pest in India. The larva feeds on the fruit of guava and pomegranate. *Catochrysops pandava* is a minor pest of Pigeon pea in India, while *Lycæna icarus* occasionally causes very slight damage to fodder crops in Europe.

Erycinidæ (*Lemoniidæ*, *Nemeobiidæ*, *Riodinidæ*).

Fore-legs on the female perfect, though shortened; in the male the tarsi of the fore-legs of one joint, without claws.

The Erycinids are mostly small butterflies, and are very variable in coloration. Many of them are of similar appearance to the Lycænids, and, as in that family, appendages are often present on the hind-wings.

The family consists of about 1,000 species, mainly from tropical South America: only about forty species occur in the Eastern hemisphere, of which one is British.

The eggs, which are similar in shape to those of the *Lycænidæ*, are laid usually singly, but sometimes in batches, on the food-plant. The larvæ vary very considerably, but

many of them resemble the *Lycænidæ* in being thickened in the centre. The larvæ of some South American species are gregarious. The pupa is short, thickened, and usually brown, and is suspended head downwards. There is no girdle of silk round the middle.

Hibernation, in the one British species, takes place as a pupa. The sexes can readily be distinguished by the character of the fore-legs, those of the female being perfect, while those of the male have the tarsi reduced to one joint, without claws.

The *Erycinidæ* are of no economic importance.

The following fascicules of *Genera Insectorum* deal with this family :—

No. 5, 1902 (sub-family *Libytheinæ*), by Pagenstecher, and No. 112 (1910), by Stichel.

Hesperiidæ.

Skippers.

The fore-legs perfect in both sexes, with a pad on the tibiæ. The antennæ gradually thickened to a club, the tips usually hooked.

The Skippers are usually small, dully coloured butterflies, with a peculiar darting flight. In appearance they resemble

Fig. 111.—Larva of Hesperiid (*Thorybes pylades*).
(Modified from Holland.)

moths, the body being short and thick, pointed at the tip, and large in proportion to the wings. The antennæ do not bear a proper club, being thickened towards the point, with the tip usually bent over to form a hook. When at rest, the wings are not held vertically above the body, but are retained half open at an angle to the body.

The distribution of the family is world-wide. Nearly 3,000 species are known, of which eight are British.

The eggs, which are round and slightly flattened, are laid

singly on the food-plant. The larvæ are usually bare, and are slightly thickened in the centre. The prothorax is constricted, which gives the caterpillar the appearance of having a neck. The larvæ of this family make much greater use of silk than do other *Rhopalocera*, and frequently spin leaves together for concealment. The pupa is elongated, with a spine at the posterior end of the body, and is, in most cases, enclosed in a rudimentary cocoon composed of a folded leaf.

Hibernation occurs in all stages: in Britain the Skippers hibernate as eggs or larvæ.

In some cases the sexes can be distinguished by the presence in the male of an oblique band of black scales on the fore-wing; in many cases, however, sex recognition is difficult.

Hesperiids are of slight economic importance. One species, *Parnara* (*Chapra*) *mathias* attacks rice in India, while others, of which *Hesperia conjuncta* from Java will serve as an example, cause injury to the foliage of sugar cane.

Sub-Order II. *HETEROCERA*. Moths

Antennæ of many diverse forms, but not clubbed; frenulum usually present. Heterocera are not, as a rule, day-flying, and generally pupate in a cocoon.

The characters of the *Heterocera* are not well defined, and the group is not a natural one. It was formerly divided into two series, *macro-* and *micro-lepidoptera;* although this was convenient, it had no scientific justification, and this method of classification has been abandoned, though the term "*micro-lepidoptera*" is still frequently used as a comprehensive name for the smaller moths. It has been proposed to form a separate sub-order of the two families *Hepialidæ* and *Micropterygidæ*, but these families agree only in the primitive character of the wings, and differ widely in many other important points.

The moths are usually easily distinguished from *Rhopalocera*, their bodies are stouter, their antennæ are not clubbed, and the wings are not held vertically above the body when at rest. The majority of moths fly in the dusk of the evening, and their coloration is, as a rule, less brilliant than that of the butterflies.

There is an enormous amount of literature dealing with

Heterocera. The more important catalogues are referred to in the introduction to the order, and volumes of the *Genera Insectorum*, where they exist, are mentioned under the families that they describe.

Syntomidæ (*Amatidæ*).

Proboscis well developed. Hind-wing with vein 8 shortened or absent and vein 1c absent; fore-wing with vein 5 nearer 4 than 6.

Syntomids are usually small moths with bright coloration, frequently with transparent patches on the wings. In appearance they are very similar to the Zygænids, and it is not always easy to distinguish the two families.

The moths fly by day; their powers of flight are feeble, and they are frequently seen resting without any attempt at concealment, so their colours are probably warning. Many members of this family mimic *Hymenoptera*. In these mimetic species the wings are transparent and the chief colours are found on the body, which is unusual in *Lepidoptera*.

About 1,200 species have been described, chiefly from the Eastern tropics. There are no British species.

The eggs are round and upright, with the micropyle at the top. They are laid in clusters on the food-plant. The larvæ are rather elongated, dull coloured as a rule, and clothed in upright tufts of hair. The pupa is dark brown, and is enclosed in a cocoon of silk and hair, usually on the surface of the soil.

The family has no economic importance.

Arctiidæ (*Lithosiidæ*).

Hind-wing with vein 8 anastomosing with the cell to near or beyond the middle; then remote from 7; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum present; larva hairy.

The Arctiids are usually small to moderate-sized moths, and are very variable in coloration. Most species are night-flyers, and many are attracted to light or sugar.

The distribution of the family is universal. About 3,000 species have been recorded, of which thirty-four are British.

The eggs are laid singly, or more frequently in batches, on the food-plant. They are rounded, with the micropyle at the top. The larvæ are densely covered in hair, which is uniformly placed over the body and usually brown. Many species have no particular food-plant, but will eat any low-growing vegetation that may be present. The pupa, which is dark brown, is enclosed in a rough cocoon of silk, hair, and leaves. Hibernation takes place as a larva or pupa, in this country usually as a larva.

The sexes are generally similar in colour and appearance, but in many cases they can be distinguished by the antennæ, which in the males are pectinate.

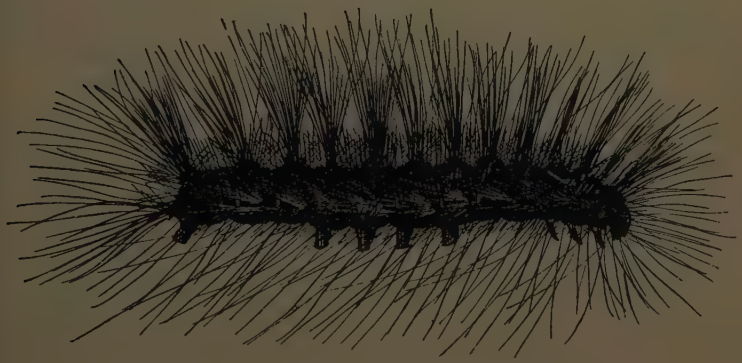


Fig. 112.—Larva of Arctiid (*Arctia caia*).

The larvæ of Arctiids are protected from birds, with the exception of cuckoos, by the hairiness of the body. In common with other lepidopterous larvæ, however, they are very frequently attacked by hymenopterous and Tachinid parasites.

Arctiidæ are divided by Hampson into three sub-families :—

i. *Arctiinæ*. Tiger moths, etc. These are the brightly coloured Arctiids, the commonest colour-scheme being red and black or white with black markings. The body is short and stout, and the proboscis frequently aborted. The larvæ, as a rule, feed on low-growing plants.

ii. *Lithosiinæ*. Footmen. These are small moths of dull colours. The wings are long and narrow, the body slender, and the proboscis well developed. The larvæ feed to a large extent on lichens.

iii. *Nolinæ*. Small inconspicuous moths, usually resting on the bark of trees during the day. The larvæ, which feed principally on the foliage of trees, have the first pair of sucker feet absent.

The *Arctiids* are not of very great economic importance, but occasionally some members of the *Arctiinæ* do considerable damage to low-growing crops, owing to their omnivorous habits and their rapid rate of increase. For an example we may mention *Spilosoma lubricipeda*, the Buff Ermine, which frequently becomes a serious pest of beet foliage in Europe.

Agaristidæ.

Hind-wing with vein 8 anastomosing with cell at base, then remote; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum present; antennæ dilated towards the tip; pupa without cocoon.

Agaristids are, as a rule, brightly coloured, day-flying moths of moderate size. One species of the genus *Ægocera* produces when flying a clicking sound, by means of a special structure on the fore-wing which rubs against spines on the front legs. The family is a small one, of about 250 species, none of which occur in Britain. It is widely distributed, with the exception of Europe.

The larvæ have few long hairs, and lateral tufts of short hair: they pupate on or just under the surface of the soil, without a cocoon. The family is of no economic importance. An account by Janet and Wytsman will be found in *Genera Insectorum*, Fasc. 16 (1903).

Noctuidæ.

Owlet-moths.

Hind-wing with vein 8 anastomosing with the cell at the base, then diverging; vein 1c absent; fore-wing with vein 5 from nearer 4 than 6; frenulum present; antennæ not dilated, of moderate length, and usually simple.

The majority of the Noctuids are of moderate size, but both very large and small moths are included in the family. The

colours are usually sombre, the fore-wings, which are narrow and stiff, being cryptically coloured, and the larger hind-wings are, as a rule, grey, generally of a lighter shade than the fore-wings. In many species, however, the hind-wings are brightly coloured. The antennæ are of moderate length, usually simple, but in a few cases pectinate in the males. In most cases the proboscis is present and well developed. The body is stout and slightly tapering: it is thickly clothed in scales and frequently tufted. Noctuids are almost entirely night-flying, and most species are attracted by light and sugar.

Fig. 113.—The Antler Moth (*Charœas graminis*).
A typical Noctuid moth.

The Noctuids are a very large family with a world-wide distribution. About 8,000 species have been recorded, of which over 300 are British.

The eggs are rounded, with a micropyle at the top: they are usually pale in colour and ribbed or sculptured. They are deposited on the food-plant singly or in batches; in the latter case the batches are sometimes covered with hairs from the base of the abdomen of the female moth. The larvæ are mainly smooth or covered with very fine hairs, and usually are cryptically coloured. Five pairs of sucker feet are present

Fig. 114.—A Typical Noctuid Larva (*Barathra brassicæ*).
(After Hargreaves.)

in most cases, but in a few species, the semi-loopers, the first two pairs are reduced or absent. The majority of the larvæ feed on the foliage of plants, either living on the plant, or, in the case of the "surface caterpillars," living on the soil and biting off the young shoots of low-growing vegetation. Some species, however, bore into the stems of plants, a few ("Boll-worms") feed in the capsules of *Malvaceæ* and other plants, and the larvæ of one genus, *Eublemma*, feed on Coccids.

Pupation usually takes place underground, in a cell of hardened soil, but sometimes in a cocoon on the surface, or more rarely on the food-plant. Hibernation takes place usually as larvæ or pupæ : a few species hibernate as adults.

The sexes can be distinguished in a few cases by the antennæ, which in the male are pectinate. Sometimes the female is larger than the male, but in the majority of cases sex recognition is difficult.

An enormous number of Noctuids have been reported as pests, many of them being of the first importance. The pests fall under several distinct groups :—

i. *Surface Caterpillars*, or *Cutworms*. Larvæ of the sub-family *Agrotinæ*, which live on or just under the surface of the soil and bite off the young shoots of low-growing plants. These larvæ are cryptically coloured and are all very similar in

Fig. 115.—Larva of Noctuid Semi-looper (*Eublemma olivacea*).

appearance. *Agrotis ypsilon*, which destroys young cotton plants in India, and other crops in many parts of the world, will serve as an example. Another cosmopolitan pest of this class is *Agrotis segetum*. Surface caterpillars are controlled by the use of poison baits, or by spraying the young plants with a stomach poison.

ii. *Army Worms*. These are caterpillars of the sub-family *Hadeninæ*, which occasionally become exceedingly abundant, and migrate in swarms, destroying numerous crops. They are particularly destructive to corn crops, wheat, maize, etc. The best-known example is *Leucania unipuncta*, which is a cosmopolitan species, but many other members of this and other genera behave in a similar manner. A British moth, whose larvæ sometimes appear in enormous numbers, is the Antler Moth, *Charæas graminis*, of the same sub-family. This

moth feeds on grasses and sometimes causes great damage to pastureland.

iii. *Bollworms.* This is the name applied to caterpillars which attack the bolls of the cotton plant. They bore into the receptacle and consume the seeds, annually causing immense damage to the cotton crop. Of the five most serious bollworms, four belong to the *Noctuidæ*. They are :—

(*a*) *Earias fabia*, which occurs in India.

(*b*) *Earias insulana*, from India, Egypt, and E. Africa.

(*c*) *Heliothis armigera* (≡ *Chloridea obsoleta*), which is a cosmopolitan insect, but attacks cotton only in the United States.

(*d*) *Diparopsis castanea*, which is found in the Sudan and in W. Africa.

The first two are both known as the Spotted Bollworm ; they belong to the sub-family *Erastiinæ*. In India they are both controlled by a Braconid parasite, *Rhogas lefroyi* ; in Egypt a similar parasite, *R. kitcheneri*, is found, but is not so effective. A third member of the genus, *E. chromataria*, does not attack cotton, but in India is a pest of jute and cultivated hibiscus.

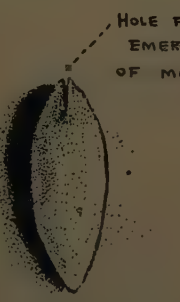


Fig. 116.—Cocoon of *Earias fabia*. (× 2.)

Heliothis (*Chloridea*) *armigera*, in the United States, is not primarily a pest of cotton, but of maize. It is only by the third brood of the insect that cotton is seriously attacked, the maize-heads then being too hard for the larva to penetrate. In India this moth, which is a member of the sub-family *Agrotinæ*, feeds in the capsules of opium.

Diparopsis castanea, the Sudan Bollworm, is a member of the sub-family *Acronyctinæ*. It causes serious damage in the Sudan and in W. Africa, but is not so important as *Earias* and *Heliothis*.

iv. *Borers.* These are principally members of the genus *Nonagria* (≡ *Sesamia*), of the sub-family *Acronyctinæ*. The eggs are laid on the leaves of the food-plant, and the larvæ bore in the stems. Their chief damage is done to cane, but maize,

wheat, and other corn crops are also attacked. *Nonagria uniformis* is the best-known example.

v. *Leaf-eaters.* A very large number of *Noctuids* fall under this class of pest. The semi-loopers, *Cosmophila*, and other genera of the sub-family *Noctuinæ*, are serious pests of cotton and jute, as well as other crops. *Prodenia littoralis*, a cosmopolitan insect of the sub-family *Acronyctinæ*, will attack many crops, including tobacco, flax, and cotton. Many members of the genus *Plusia*, sub-family *Plusiinæ*, are pests, particularly on flax. *Caradrina* is another genus whose members cause immense damage. In Britain the two most serious pests are *Hadena oleracea*, which attacks tomatoes under glass, and *Mamestra brassicæ*, which attacks cabbages and other crucifers. Both these insects belong to the sub-family *Hadeninæ*.

Pterothysanidæ.

Hind-wing with vein 8 approximated to 7 at the middle of the cell; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum absent.

These are large day-flying moths, with slender bodies and simple antennæ. The colouring is black and white, and the hind-wings are fringed with long hairs. *Pterothysanidæ* consist of a single genus from Eastern India. There are very few species, and the life-history is unknown. They are of no economic importance.

Lymantriidæ (*Liparidæ*).

Tussock moths.

Hind-wing with vein 8 connected to cell by a bar; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum present; proboscis aborted; larvæ hairy, with upright tufts.

Lymantriids are small to medium-sized moths, the coloration usually dull. They are usually stoutly built moths with antennæ of moderate length, and always pectinate in the male. In no case is the proboscis functional. The female usually has

an anal tuft of hairs ; in a few cases the wings of the female are aborted. The majority of Lymantriids are nocturnal.

The family is a widely distributed one of about 800 species ; of these ten are British.

The eggs, which are round and slightly flattened, are laid in

Fig. 117.—Eggs of Vapourer Moth (*Orygia antiqua*). (× 10.)

batches on the food-plant ; often they are covered with fur from the anal tuft of the female. A very large number are laid by one female. The larvæ are hairy, with thick upright tufts along the body. The hair from these tufts is often barbed and poisonous, setting up a considerable irritation if it enters

Fig. 118.—A typical Lymantriid Larva of *Dasychira pudibunda* (about nat. size).

the skin. In a few cases the larvæ are colonial, forming a common web or tent over part of the food-plant. Pupation takes place in a loose cocoon of silk and hair, usually on the surface of the soil or on the food-plant. The pupa is hairy, which is very unusual : the hairs, like those of the larvæ, are often irritant. Hibernation takes place in the egg, larval, or pupal stages ; in this country principally as a larva.

Fig. 119.—Cocoon of Drinker Moth (nat. size).

The sexes can be distinguished by the antennæ, which are pectinate in the male; in many cases the females possess an anal tuft of hair, and occasionally their wings are aborted.

Lymantriids are not an important family economically, though a few species are serious pests. The most important are probably the Browntail (*Euproctis chrysorrhœa*) and the Gipsy (*Lymantria dispar*), which are serious pests of fruit trees in Europe and in America, particularly in the latter country, where both have been accidentally introduced. Another important insect is the Black Arches (*Lymantria monacha*) which occasionally causes serious damage to forest trees in Europe, particularly in Germany. All these three species occur in England, but they are all comparatively rare, and none can be regarded as a pest.

Hypsidæ (*Aganaidæ*).

Hind-wing with vein 8 connected to the cell by a bar; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum present; proboscis well developed.

Hypsids are usually brightly coloured moths of moderate size; they are day-flying and have the proboscis well developed.

The family is a small one, and its distribution is confined to the tropical and sub-tropical regions of the East.

The eggs are laid singly or in batches on the food-plant. The larvæ are brightly coloured with few hairs; they feed by day and make no attempt at concealment. Pupation takes place on the surface of the soil, in a flimsy cocoon. Hibernation usually occurs in the pupal stage.

The sexes can sometimes be distinguished by the form of the antennæ; in most cases, also, the coloration of the female is brighter than that of the male.

Few of this family are pests. Three members of the genus

Argina attack Sann Hemp in India, feeding on the leaves and pods: of these *A. cribraria* is sometimes a serious pest. A few species of *Hypsa* occasionally become sufficiently abundant in India to defoliate large shade trees.

Sphingidæ.

Hawk-moths.

Hind-wing with vein 8 connected to cell by a bar at the base, then approximated to 7; vein 1c absent; fore-wings long and narrow, with vein 5 from the middle of the cell or nearer 6 than 4; frenulum present; proboscis well developed; antennæ short and thick. Larva smooth, with an anal horn, pupating in soil without cocoon.

Sphingids are moderate-sized to large moths, of very characteristic appearance. The fore-wings are long and narrow, usually cryptically coloured: the hind-wings are small, often

Fig. 120.—Larva of Sphingid (*Chœrocampa elpenor*) (slightly less than nat. size).

of much brighter coloration. In a few species the wings are practically transparent, very few scales being present. The body is very stout and usually pointed at the tip, though in a few cases it is furnished with an anal tuft of long dense hairs. The antennæ are short and stout, and frequently hooked at the tip. The proboscis is well developed, and frequently of great length, in some cases measuring nearly ten inches. Sphingids have a very rapid and powerful flight; most of them fly at dusk, but a few species, the Humming Bird moths, by day. They do not settle when taking nectar, but hover over the flower. In a few cases the moths can produce a shrill squeaking sound, possibly by forcing air through the proboscis.

Both larvæ and pupæ of certain species are also credited with the power of producing sounds.

The family is a large one, with a world-wide distribution. There are seventeen British species. The classification and nomenclature have recently (1907) been revised by Jordan and Rothschild. There is also an account of the family by the same authors in *Genera Insectorum*, Fasc. 57 (1907).

The eggs, which are rounded, with a micropyle at the top, are laid singly on the food-plant. The larvæ are very large, and are usually cryptically coloured, with a hornlike process on the eighth abdominal segment. Frequently large "eyespots" are present on the sides of the thorax, presumably in order to frighten enemies. The caterpillar of *Pseudosphinx tetrio* of South America is brightly coloured in red, black, and yellow: it feeds on the foliage of a tree, and is a very conspicuous case of warning coloration. Just before pupation, some larvæ become brown in colour, as otherwise they would be conspicuous objects when they crawled to the ground to pupate. In most cases pupation takes place in the soil, in a cell of earth, but occasionally a rough cocoon of silk and rubbish is constructed on the surface of the ground. The pupa is dark brown; in some cases there is an external sheath for the proboscis. Hibernation usually takes place as a pupa in the soil, but in this country one species, *Macroglossa stellatorum*, has been reported to spend the winter as an imago. The sexes can usually be separated by the antennæ, which, in the male, have a ciliated chitinized ridge on the under-side; this character, however, is not always easy to distinguish.

Fig. 121.—Pupa of a Sphingid Moth. (× ½.)

Sphingids are rarely abundant, but there are species which are destructive to tobacco in the United States—*Protoparce 5-maculatus* being the chief offender—and to sweet potato, which is attacked by the cosmopolitan *Herse convolvuli*. Coffee in Malaya was destroyed by the larvæ of a Humming Bird Hawk-moth.

Cymatophoridæ (*Thyatiridæ*, *Polyplocidæ*).

Hind-wing with vein 8 not connected to cell, but approximated to 7; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum present.

These are small moths, which in appearance and habits resemble the Noctuids. The proboscis is well developed, and the antennæ are of moderate length. The body is short and rather stout.

Cymatophorids are a small family, but are widely distributed, particularly in temperate regions. There are nine British species.

The eggs are oval and ribbed and are laid singly or in batches on the food-plant, usually on the edges of the leaves. The larvæ are smooth, usually cryptically coloured, and feed at night, resting during the day in a shelter formed of leaves spun together. The pupa is brown or black, and is enclosed in a loose cocoon usually placed on the surface of the soil among dead leaves. Hibernation takes place as a pupa in the cocoon. Cymatophorids are of no economic importance.

Eupterotidæ.

The hind-wing with vein 8 remote from 7; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum present; proboscis aborted. Larva uniformly hairy, pupating in a cocoon of silk and hair.

Eupterotids are large moths, usually of dull coloration. The antennæ are of moderate length, and are pectinate in both sexes, but the pectination is much more pronounced in the male. The proboscis is aborted, but the palpi are present and are hairy.

The family has a world-wide distribution, occurring principally in tropical and sub-tropical regions. There are no British species.

The eggs are round, and are deposited usually in batches on the food-plant. The larvæ resemble those of Arctiids, being covered with a uniform clothing of dense long hairs. In

many species the hairs are barbed or poisonous, and cause great irritation if they enter the skin. The larvæ of the majority of species are gregarious, feeding on forest trees. The caterpillars of the European Processionary moth, *Cnethocampa processionea*, which feed on oak, have the curious habit of moving from one tree to another in orderly wedge-shaped columns. In the African genus *Anaphe*, the larvæ construct a large web-like shelter, beneath which they rest and in which they later pupate. These structures are said to attain sometimes a length of several feet. The larvæ of the South American genus *Palustra* are aquatic, swimming by alternately coiling and straightening the body. The mode of respiration is not known, but air is probably carried amongst the hairs of the body. A few species pupate under water. The pupa is enclosed in a cocoon of hair and silk, which is usually attached to the food-plant. Hibernation takes place as a pupa in the cocoon.

In many cases the sexes can be distinguished by the antennæ, which are more strongly pectinated in the male than in the female.

Eupterotids are of very slight economic importance. None are pests, though the larvæ of certain species may cause a small amount of damage by the defoliation of forest trees. The envelope in which the larvæ of the genus *Anaphe* spin their cocoons is used to a small extent for silk ; but the silk is coarse, and of little value.

Notodontidæ.

Prominents.

Hind-wing with vein 8 connected to 7 near the middle of the cell ; vein 5 obsolescent ; vein 1c absent ; fore-wing with vein 5 nearer 6 than 4 ; frenulum present ; proboscis present.

Notodontids are moderate-sized to large moths, generally dull in appearance, brown and grey being the commonest colours. In appearance the majority resemble Noctuids, and like the members of that family they are nocturnal. In many cases there is a tooth-shaped tuft of scales about the middle

of the inner margin of the fore-wings : when the moths are at rest these tufts are brought together and project above the general profile of the wings. The antennæ are of moderate length and are frequently bipectinate in the males. The body is fairly stout, long, and usually tapering : there is frequently a tuft of long hairs at the apex of the abdomen. The proboscis is present, and the moths will come to sugar patches : a bright light, however, has an even greater attraction for them.

Notodontids are a large family with a wide distribution, particularly in temperate countries. There are twenty-five British species.

The eggs are laid singly, or more frequently in pairs or batches on the food-plant. They are rounded, and usually whitish, with the micropyle at the top. The larvæ, which feed principally on the foliage of trees, differ very largely in

Fig. 122.—Larva of Puss Moth (*Dicranura vinula*) (about nat size).

appearance : some are quite normal, with few hairs and five pairs of sucker feet ; others have curious processes on various parts of the body ; and in a few the body has undergone more complete modification. The two chief types of the last class are *Cerura vinula*, the Puss Moth, and *Stauropus fagi*, the Lobster, both of which occur in this country. In the former, and in the larvæ of allied species, the body is stoutest in front, tapering almost to a point at the apex, which is held in the air. The anal claspers are modified to form a pair of tubes, in which are concealed long flexible flagellæ, which are capable of being everted with great rapidity. The larvæ of *Stauropus* and its allies are even more curious than that of *Cerura*. The first five segments of the body are held erect, when the larva is resting, with the second and third pairs of legs, which are extremely long, outstretched. The apex of the abdomen, which is also held erect, is bulbous, and the anal claspers are

represented by two long, slender processes. The curious form of these larvæ, as well as the unusual attitudes they adopt, are supposed to protect the insects from the attacks of Ichneumons and other enemies, but evidence is wanting that these larvæ are less parasitized than others of more conventional form.

The pupa is brown or black, and a tightly woven cocoon of silk, together with leaves or other material, is formed. It is placed on the food-plant, in crevices in bark, or on or under the surface of the soil. In this family two devices are found to aid the imago in escaping from the cocoon. In some species a caustic fluid, which softens the silk, is emitted, while in others the pupa is provided with sharp processes, with which an exit hole is cut out. Hibernation usually takes place as a pupa in the cocoon.

The sexes can be distinguished as a rule by the antennæ, which in most cases are bipectinate in the male.

Notodontids are of slight economic importance, one species, *Stauropus alternus*, being a very minor pest on tea in Ceylon.

Geometridæ.

Hind-wing with vein 8 usually connected with 7 at the base; if not, vein 5 fully developed; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum present. Larvæ with sucker feet reduced to the last two pairs.

Geometrids vary considerably in size, but the majority are rather small. The wings are fragile, and are cryptically coloured as a rule in various shades of grey, with patterns composed of wavy lines, which in most cases extend across both pairs of wings. They are mostly night-flying, and rest during the day with their wings open and pressed down on the surface on which they are settled. Many of the smaller ones are whitish with irregular blotches of black, and in this position bear a close resemblance to bird's excrement. A large number of species are attracted to light and sugar. The body is slender, with antennæ of moderate length, often pectinate in the males. The proboscis is usually well developed. In a few species the females are wingless.

The Geometrids constitute a very large family, with a world-wide distribution. There are about 270 British species.

The eggs are laid singly or in batches on the food-plant. They are round or oval, slightly flattened, and usually ribbed. The larvæ, which are generally brown or dark green in colour, are slender and elongate, with the sucker feet reduced to the last two pairs. The mode of progression of the larva is peculiar, consisting of an alternate advancing of the front and hind portions of the body, the body being first extended to its full length and then raised in the form of a loop. This habit has given rise to the Latin name of the family, and to the English name of "Loopers" for the caterpillars. In America the larvæ are known as "Span-worms." Pupation usually takes place in a slight cocoon either on the food-plant, or on, or just underneath, the surface of the ground. Hibernation usually takes place either as a larva or a pupa: occasionally as an imago.

FIG. 123.— A typical Geometrid Moth, the Clouded Border (*Lomaspilis marginata*) (rather more than nat. size).

FIG. 124. — Geometrid Larva (*Ourapteryx sambrucaria*).

The sexes can in many cases be distinguished by the antennæ, which are pectinate in the male only. In a few species the females are wingless.

Geometrids are not a very important group economically, but the family contains some serious pests. *Boarmia bhurmitra* is sometimes abundant on tea in Ceylon, occasionally causing the loss of an entire crop. In this country *Cheimatobia brumata*, the Winter Moth, and allied species, cause a great deal of damage to fruit trees. The eggs are laid in winter on the twigs of fruit trees, and the larvæ feed

on the young foliage in April and May. The usual remedy adopted is the placing of "grease-bands" round the tree trunks, to prevent the wingless females from ascending, but this is not very effective, and spraying is usually necessary. This pest is found throughout Europe and also in North

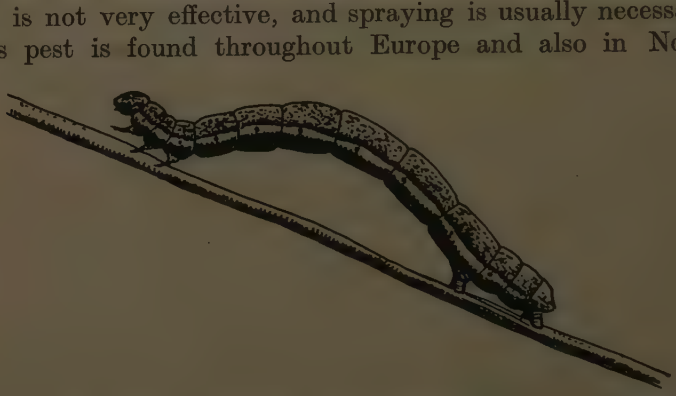


Fig. 125.—Larva of Geometrid (*Nyssia zonaria*). ($\times$ 1½.) (Looper.)

America. The chief American pests, however, are the Canker Worms, *Alsophila pometaria*, and *Paleacrita vernata*, and the Apple Span Worm, *Ennomos subsignaria*.

Certain sections of the family have been described by Prout in *Genera Insectorum*, Fasc. 103, 104, and 129, 1910–1912.

Saturniidæ.

Wild Silk Moths.

Hind-wing with vein 8 diverging from the cell at the base; vein 1c absent; fore-wing with vein 7 connected to 8 and 9; vein 5 nearer 6 than 4; frenulum absent; proboscis absent. Larva usually brightly coloured with hair-bearing processes, pupating in a silken cocoon.

These are all large moths, usually brightly coloured, with eyespots or clear patches in the wings. The body is short and stout, and the wings are very large: the hind-wings are in a few produced into tails. The antennæ are short and strongly bipectinate in the male. There is no proboscis, and the life of the perfect insect is very short. Saturniids are usually nocturnal, but the males of some species may be seen flying

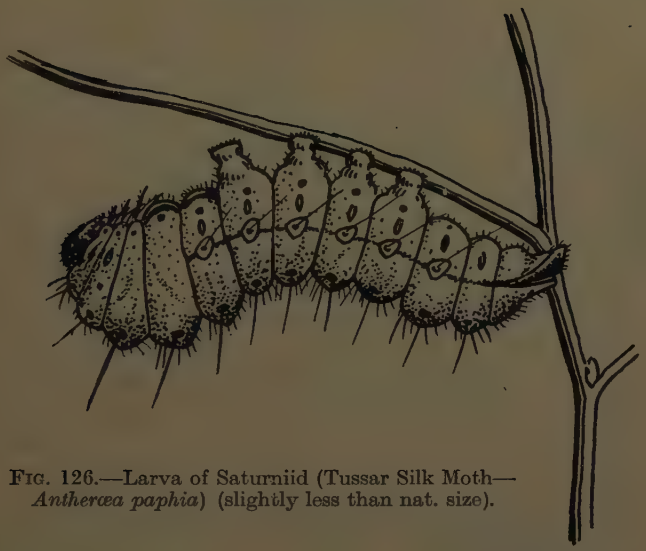


FIG. 126.—Larva of Saturniid (Tussar Silk Moth—*Antheræa paphia*) (slightly less than nat. size).

with rapid darting movements in bright sunlight. Sex attraction is very marked in this family, a female exposed in the open attracting many males, even from a considerable distance. This phenomenon, which is found in several families, is known as "assembling."

Saturniidæ are a fairly large family, with a world-wide distribution. There is one British species.

The eggs are rounded and smooth, and are laid singly, or more usually in batches on the food-plant. The larvæ are stoutly built and frequently brightly coloured, with a series of processes, each bearing a tuft of hairs, arranged along the body. The food consists in the main of the foliage of forest trees. The pupa is dark brown, and is enclosed in a tightly woven cocoon of silk, from which the moth emerges either by emitting some caustic fluid, which softens the silk,

FIG. 127.—Stalked Cocoon of Tussar Silkworm.

or else through a cleverly constructed exit hole, which, while allowing the moth free egress, does not permit of the intrusion of enemies from outside.

Fig. 128.—Pupa of *Attacus ricini* (nat. size).

The sexes can easily be distinguished by the antennæ, which, as already mentioned, are strongly bipectinate in the male. There is frequently also a considerable difference in size, the females being decidedly larger than the males. Hibernation usually takes place as a pupa in the cocoon. The economically important species are summarized on page 331.

Bombycidæ.

Hind-wing with vein 8 remote from 7 and connected or approximated to the cell; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum absent; proboscis absent. Larva smooth, with an anal horn or with dorsal processes.

These are small moths, usually of dull coloration, with the wings and body very densely covered in scales. The antennæ are bipectinate in both sexes, and the legs short and hairy. There is no proboscis, and the life of the imago is very short.

The Bombycids are a small family of less than 100 species; they are, however, widely distributed in the tropical and sub-tropical regions of the world. There are no British species.

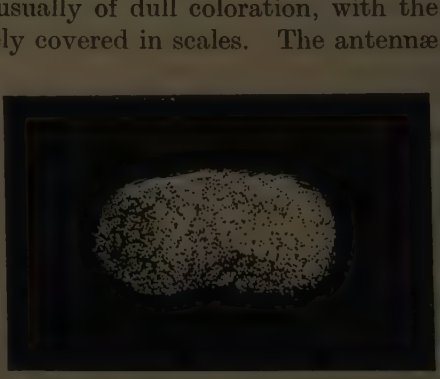


Fig. 129.—Cocoon of *Bombyx mori* (about nat. size).

The eggs are white and rounded, and are laid in batches on the food-plant. The larvæ are smooth and elongate, and frequently there is a slender horn on the last abdominal segment. In other cases there is a series of dorsal processes,

throughout the length of the body. The pupa is enclosed in a silken cocoon. There is no obvious character by which the sexes can be separated, but in many cases the female is considerably larger than the male. Hibernation in the domesticated species (*Bombyx mori*) occurs in the egg stage.

The family contains one very important species—*Bombyx mori*, the mulberry silk moth, which produces the bulk of the world's supply of silk. This insect, whose life-history is elsewhere described, is probably indigenous to China, but it has been domesticated for centuries and spread throughout the world. It may still occur wild on the slopes of the Himalayas, far up the valleys of Kashmir, or in some sub-montane area in that part of the world.

Brahmæidæ.

Hind-wing with vein 8 approximated to or anastomosing with 7; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum absent; proboscis present; pupa without cocoon.

These are large moths, of which the colours are usually sombre, with complicated patterns on the wings. The antennæ are bipectinate, and the proboscis present.

The family is a small one, consisting of about fifteen species, which are confined to the warmer regions of the Eastern hemisphere. There are no British species.

Little is known of the life-history of this family. The larvæ of some species have the second and third segments swollen, and in some cases there are spines on the anterior part of the body. A cocoon is not formed.

Brahmeids are of no economic importance.

Ceratocampidæ.

Hind-wing with vein 8 diverging from the cell at the base; vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum absent; proboscis present; tibiæ with spurs. Larva usually spiny, pupating in the ground without a cocoon.

These are medium-sized to large moths, and are mainly brightly coloured. The body is short and fairly stout: the

antennæ short and pectinate. The proboscis is always present, but in some cases it is not well developed. The moths are usually nocturnal in habit, and a bright light has a strong attraction for them.

The distribution of the family is limited; it is confined to the New World, most of the species occurring in the tropical districts. About sixty species have been recorded.

The eggs are rounded, and are deposited singly or in batches on the food-plant. The larvæ are usually brightly coloured: they are without hairs, but with a series of stout bristles or protuberances arranged along the body. They usually feed on the foliage of trees, and pupate under the surface of the soil. A cocoon is not formed. Hibernation usually takes place as a pupa.

The sexes can frequently be distinguished by the antennæ, which are more strongly pectinate in the male than in the female.

Ceratocampids are of no economic importance.

Uraniidæ (including *Epicopeiidæ* and *Epiblemidæ*).

Hind-wing with vein 8 diverging from 7 at the base; vein 1c absent; fore-wing with vein 7 remote from 8 and 9, and usually stalked with 6; vein 5 nearer 6 than 4.

The moths in this family are very diverse in size and appearance: some are small and dully coloured, while others are of large size, and possess a brilliant metallic coloration. In many cases the moths resemble Swallowtail butterflies, having a similar coloration, and similar processes on the hind-wings. In the majority of species the wings are fairly large, the bodies slender, and the entennæ are filiform.

The family is a small one, but is widely distributed in the warmer regions of the world. There are no British species.

Little is known of the life-history of this family. The larvæ vary very considerably: many being greatly ornamented, some with long white waxy processes, others with long dark hairs; others again resemble noctuid caterpillars, except for dorsal fleshy processes.

Pupation usually takes place on the surface of the soil, in a thin silken cocoon.

Uraniids are of no economic importance.

Fascicule 16, 1903, of the *Genera Insectorum*, by Janet and Wytsmann, deals with the *Epicopeiidæ*, which are here included with *Uraniidæ*.

Psychidæ.

Bag worms, Case weavers.

Female wingless in a case. Male winged, with imperfect scales; hind-wing with vein 8 free or connected to cell by a bar; vein 1c present; fore-wing with vein 1c present; proboscis absent. Larva of both sexes in a case.

These are small to moderate-sized moths of dingy colours. The scales are imperfect and there are no definite patterns on the wings. The antennæ, in the male, are bipectinate; in the female they are aborted or absent. The female, which remains in the larval case, is wingless, but the amount of degeneration with regard to the other appendages varies considerably; in some cases the legs are well developed, but in others the moth has become maggot-like, the legs being absent and the head much reduced in size.

Fig. 130.—Larva of Psychid (*Mahasena graminivora*).

The family is a large one, with a world-wide distribution: there are nine British species.

Copulation takes place in the larval case of the female, the male inserting its long flexible abdomen into the opening at the top of the case. The female lays the eggs inside the case

and then dies. The larvæ on hatching leave the parent case, and before feeding construct cases of their own, from pieces of vegetable matter interwoven with silk. So hard and strong are the cases that they are frequently mistaken for shells. The structure of the larvæ is quite normal, and it moves about readily, dragging the case with it. Pupation takes place inside the case. The pupa of the male is normal; that of the female is usually without wing-cases, but these occur in the pupæ of some species. Parthenogenesis is known to occur in one species of the family. Hibernation usually takes place in the egg stage.

Although one or two species have been reported as injurious to certain trees, particularly in the United States, there are really no definite pests among the *Psychidæ*.

Heterogynidæ.

Female wingless in the cocoon. Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; fore-wing with vein 1c present; proboscis absent. Larva free.

This is a family of one genus only, *Heterogynis*, from the South of Europe. The male moth is very similar in appearance to the males of some species of Psychids, being small and dusky-coloured, with imperfect scales. The female is destitute of wings and appendages, and remains in the cocoon, where the eggs are laid. The larvæ are greyish: they are elongate and taper slightly at each end. The pupa is dark brown or black, and is enclosed in a thin oval cocoon of grey or yellow silk.

Heterogynids are of no economic importance.

Arbelidæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; fore-wing with vein 1c absent; frenulum absent, proboscis absent. Larva boring in trees or bushes, feeding on the bark and pupating in the bore.

The members of this family are small moths of dull colours. The body is long and slender, and frequently is tufted with

hairs at the apex. The antennæ are of moderate length, and are bipectinate in the male. There is no proboscis. The moths are nocturnal in habit, and are only to a slight extent attracted to light.

Arbelids constitute a small family, and are found in the tropical and sub-tropical regions of the Old World.

The eggs, which are oval and pale green in colour, are laid singly on the bark of the food-plant. The larvæ are dark and smooth; they construct a short tunnel in the stem, in which they rest during the day time. At night they leave the tunnel and feed on the bark surrounding the entrance hole, underneath a web which they construct of silk, macerated bark and excrement. Pupation takes place in the bore, without the formation of a cocoon. The pupa is long and slender; the abdominal segments are flexible and armed with hooks, by means of which the pupa can move freely in the tunnel. The winter is spent in the larval stage.

The sexes can be distinguished by the antennæ, which are bipectinate in the male: the female is usually larger and paler in colour than the male.

Several members of this family are pests, as they feed on the bark of fruit and other useful trees. The most serious, however, are those species that attack tea, of which *Arbela dea* is the most important. This moth annually causes damage to tea in India, and no satisfactory means of dealing with it has yet been discovered.

Argyrotypidæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; fore-wing with vein 1c absent; frenulum present; proboscis absent.

This family contains but three species, two from Madagascar and one from Chili. They are moths of moderate size, with slender bodies and pectinate antennæ. The life-history is unknown, and the moths have no economic importance.

Ratardidæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; fore-wing with vein 1c present; frenulum absent; proboscis absent.

This family contains one species only, *Ratarda marmorata*, from India. This is a slender moth of medium size; it is dark in colour, with slight fringes to the wings and with pectinate antennæ. The proboscis is absent. The life-history is unknown, and the moth is of no economic importance.

Cossidæ.

Hind-wing with vein 8 free or connected to the cell by a bar and remote from 7; vein 1c present; fore-wing with vein 1c present; frenulum present; proboscis absent. Larva boring in wood and pupating in the tunnel.

These are moderate-sized to large moths, of dull colours, grey or brown being predominent, with vague patterns on the wings. The wings are long and narrow, with the scales frequently imperfect. The antennæ are short and usually bipectinate, but sometimes simple in the female. There is no proboscis. Cossids are nocturnal in habit, and are attracted to light.

The eggs are laid, as a rule, in crevices in the bark of trees. The larvæ are smooth, but occasionally have a few stiff bristles scattered along the sides. They are whitish or pale pink in colour. The larvæ of certain species give out a strong odour, for example, *Cossus cossus* in this country, of which the larva has a smell resembling that of the goat; the moth is called the goat moth in consequence. Most of the larvæ tunnel in the wood of trees, but sometimes dead wood is also attacked. A few species bore in the stems of reeds. The life-history is slow, the larval stage frequently occupying several years. The pupa is dark brown and is enclosed in a rough cocoon of silk and macerated wood inside the bore. Hibernation takes place as a partially grown larva or as a pupa.

The sexes can usually be distinguished by the size, the male being markedly smaller than the females. In addition, the

antennæ of the male are more strongly pectinate than those of the female.

Apart from slight damage caused to trees grown for timber or ornament, certain species of this family are pests as they attack the stems of crop plants. The most important is probably *Zeuzera coffeæ*, which bores into the stems of coffee in India and Java. *Cossus cossus* and *Zeuzera pyrina* in this country occasionally attack fruit trees.

Lasiocampidæ.

Hind-wing with vein 1a reaching the outer margin; vein 8 curved, and approximated to or anastomosing with 7; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum absent; proboscis absent. Larva with lateral tufts of hair, pupating in a cocoon of silk and hair.

The majority of the moths in this family are of medium size, though some are large. Brown is the predominant colour. The body is fairly long and stout, and is frequently furnished with an anal tuft in the female. The antennæ are pectinate in both sexes, but more strongly so in the male than in the

Fig. 131.—Larva of Lasiocampid (*Gastropacha quercifolia*). (× ⅘.)
(As drawn from above, neither the legs nor sucker feet are visible.)

female. The proboscis is absent. Most of the Lasiocampids are nocturnal and will come to light: the males of a few species fly rapidly in an erratic, darting manner in bright sunlight. Assembling is of frequent occurrence in the family.

The distribution of the family is world-wide: over 500 species have been described, of which eleven are British.

The eggs, which are round and slightly flattened, are laid in patches on the food-plant, either on the foliage or on the twigs. They are frequently covered with hairs from the anal tuft of the female. The larvæ are elongate, and are usually brown

in colour: they are armed with lateral "shaving-brush" tufts of hair, which are easily detachable, and cause great irritation if they enter the skin. The caterpillars are often gregarious, constructing a common shelter of silk under which they rest by day. The pupa is dark brown or black, and is enclosed in a cocoon of tightly woven silk and hair, placed on the food-plant or on the surface of the soil. Hibernation takes place in the egg larval or pupal stage: in one case in this country the imago emerges in winter. Occasionally the moths pass several years in the pupal stage.

The sexes can usually be distinguished without much difficulty, the females being larger, paler in colour, and with the antennæ less strongly pectinate, than the males.

Certain species in this family are leaf-eating pests, the most important being the Lackey, *Malacosoma neustria*, and allied species, on apple. The larvæ of these moths are known as Tent caterpillars, as they are gregarious and spin a common web. In certain years they abound, and completely defoliate whole orchards. They are controlled by an arsenical spray, or by the destruction of the shelters. The Lackey is a European moth, but similar pests of the same genus occur in North America. These moths are attacked by parasites, particularly Tachinid flies, to a very great extent.

Endromidæ.

Hind-wing with vein 8 connected with the cell by a bar near the base; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum absent.

This family consists of one species only, *Endromis versicolor*, the Kentish Glory. It is found throughout central and northern Europe, including Britain.

Endromis is a large moth, brown or buff in colour, with two black cross-lines on the wings, and a V-shaped black mark in the centre of the fore-wings. The antennæ are of moderate length, pectinated in the male and slightly so in the female; the proboscis is aborted. The males fly strongly in the sunlight, but the females do not become active until night. "Assembling" is characteristic of this species: as many as a hundred males have been observed to visit one female.

The eggs are oval, and greenish-brown in colour: they are laid in rows on twigs of birch. The larvæ, which are green, dotted with black, are stout, tapering forward from the third abdominal segment to a small head. There is a thick horn-like prominence on the last segment. When young, the larvæ are darker in colour, and when resting cluster on the twigs of the food-plant. The pupa is brown, with a series of spines on the abdominal rings: it is enclosed in a tough cocoon which is placed generally on, but sometimes just underneath, the surface of the soil. A few days before the emergence of the imago, the pupa, by means of its abdominal spines, wriggles partially out of the cocoon. Hibernation takes place as a pupa in the cocoon.

The sexes are easily distinguished: the males are smaller, darker and have more strongly pectinate antennæ than the females, and are day-flying.

Endromids are of no economic importance.

Chrysopolomidæ.

Hind-wing with vein 8 remote from 7 and anastomosing with the cell; vein 1c present; frenulum absent; palpi present.

This family consists of one African genus, with but few species. The moths are yellow or buff in colour, and are of moderate size. The bodies are short and rather slender, and the antennæ are bipectinate. The life-history is unknown, and the moths are of no economic importance.

Perophoridæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; fore-wing with vein 9 widely separated from 8; frenulum absent; proboscis absent. Larvæ case-dwellers, pupating in the case.

The moths belonging to this family are of medium size, and are dully coloured, usually brown. There is no proboscis.

The family is a small one, and in distribution is confined to the New World, chiefly tropical S. America.

The eggs are laid singly or in batches on the food-plant.

The larvæ are very varied in form, some being elongate, and others short and thickened. In most cases they possess a number of curious appendages on the head. These are short and slender, and their function is unknown. All the larvæ live in cases, which they carry about when feeding: when at rest they usually attach the cases to the food-plant by silken threads. They will, however, readily leave their cases if alarmed. The cases are usually constructed of leaves, which are folded and spun together with silk: in one species, *Perophora sanguinolenta*, the case is constructed of the caterpillar's excrement. Pupation takes place inside the case: the pupa is capable of movement and has rows of spines on the abdominal segments.

Perophorids are of no economic importance.

Megalopygidæ (*Lagoidæ*).

Hind-wing with vein 8 remote from 7 and anastomosing with the cell; vein 1c present; frenulum absent; palpi absent. Larva with 7 pairs of sucker feet.

This family is a small one, and is confined to the New World, being found chiefly in tropical S. America.

The moths are small and of light colours, yellow or buff being predominant. The bodies are stout and thickly covered in hairs: there is frequently an anal tuft in the female. The antennæ are of moderate length and are bipectinate.

The larvæ are elongate, and possess seven pairs of sucker feet instead of the usual five. They are covered with long silky hair, and in some cases are also furnished with poisonous bristles. Pupation takes place usually underground in a tight cocoon furnished with a trap-door for the emergence of the imago.

None of the Megalopygids are of economic importance.

Limacodidæ (*Eucleidæ; Heterogeneidæ; Cochlididæ*).

Hind-wing with vein 8 distinct from 7 and anastomosing with the cell; vein 1c present; frenulum present. Larvæ slug-like, without sucker feet.

These are mainly small moths, usually dull brown in colour, but occasionally apple-green. The body is short and the wings

rounded. There is no proboscis. The moths are night-flying. The distribution of the family is wide, but mainly tropical: about 400 species are known, of which two are British.

The eggs are oval and flat, and are laid usually in batches on the food-plant. The larvæ vary greatly in appearance, but are always destitute of sucker feet and have the thoracic legs much reduced. In some species the caterpillars have a series of protuberances on the body; in other cases they are covered with a thick skin, which hides all traces of segmentation; while in others again they are clothed with spines, which in many tropical forms are developed to an enormous extent, and are frequently poisonous. The general shape of the larva is short and oval, and the head in many cases is retractile. The pupa is enclosed in an oval cocoon of silk, which is generally placed among the leaves of the food-plant. The cocoon is provided with a definite lid, which is pushed open by the pupa before the emergence of the moth. Hibernation usually occurs as a full-grown larva in the cocoon. The family has little economic importance: a few species, however, are minor pests. Among these we may mention: *Belippa laleana*, which feeds on Cinchona in India; *B. albiguttata*, on tea in Java; and *Parasa virida*, which injures coffee in British E. Africa.

FIG. 132.—Limacodid Larva (*Parasa lepida*). (× 3.)

DALCERIDÆ.

Hind-wing with vein 8 free or connected to the cell by a bar and remote from 7; vein 1c present; fore-wing with vein 1c present; frenulum present; hind-wing extending beyond the abdomen; proboscis absent.

This is a small family peculiar to the neotropical region. The moths are of small to medium size, and usually of dull colours. They are day-flying. The body is short, and the hind-wings are wide and extend beyond the apex of the abdomen. The antennæ are pectinate, and there is no proboscis.

The larvæ of only two species appear to be known. Of these, one is pale green and the other is white and translucent. They resemble the larvæ of the Limacodids, the abdominal feet being absent and the movement like that of a slug. The body has a series of small protuberances, which break off at the slightest touch.

The species of this family are described by Dyar (*Proc. Ent. Soc. Wash.* 1910, p. 113).

Neocastniidæ.

Hind-wing with vein 8 free and remote from 7; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; proboscis absent; antennæ clubbed.

This family consists of three species only, from the warmer regions of the East. They are large moths, resembling butterflies of the family *Nymphalidæ* in appearance. None are of any economic importance, and their life-history is unknown.

Castniidæ.

Hind-wing with vein 8 free, diverging from the cell at the base; antennæ clubbed; proboscis present; frenulum present.

The Castniids constitute a small family whose members are confined to S. America and Australia. In size they are very varied, ranging from small to very large forms. They resemble *Rhopalocera* in appearance and habit, but can readily be distinguished from that group by their possession of a frenulum. The antennæ are long, and are clubbed or hooked at the tip. The larger forms are dark with paler markings, and resemble the Nymphalids. The smaller ones, belonging to the Australian genus *Synemon*, resemble the Hesperiids. They fly over grass-land in hot sunshine, and rest with their wings folded vertically over the body.

So far as is known, the larvæ bore in the stems of plants. The life-history of one species only, *Castnia licus*, has been studied in detail. This is a large insect which is a pest of sugar-cane in B. Guiana and in some parts of the W. Indies,

and in Trinidad also attacks banana. It causes serious damage as the larva is of large size, and constructs a correspondingly large tunnel. The eggs, which are oval and pointed at each end, are laid singly inside the leaf-base of the plant. The larvæ on hatching tunnel into the stem, and when full grown pupate inside the tunnel in a cocoon of silk and wood-chips.

Euschemonidæ.

Hind-wing with vein 1c absent; fore-wing with vein 5 nearer 6 than 4; frenulum present; antennæ clubbed.

This family consists of one species only, *Euschemon rafflesiæ*, from Australia. It is a medium-sized moth, dark in colour, with light patches, and with long antennæ. In appearance it is very similar to a large Hesperiid butterfly, and is a day-flying insect. It is of no economic importance, and its life-history is unknown.

Zygænidæ.

Burnets.

Hind-wing with vein 8 approximated to the cell and connected to it by a bar; vein 1c present. Proboscis usually present. Middle spurs of hind-tibiæ very short or absent.

The Zygænids comprise a large family and are widely distributed in both tropical and temperate regions. There are ten British species. The moths are mainly diurnal in habit. The family is divided into three sub-families, which differ largely in appearance. The *Zygæninæ*, to which all the temperate and a large number of the tropical species belong, are small moths with stout rounded bodies. The colours are bright, combinations of red, black and green being the commonest. The antennæ are long, slightly thickened and hooked at the tip, and are not pectinate. The proboscis is well developed. The *Chalcosiinæ* are large moths with pectinate antennæ and a well-developed proboscis. The coloration is bright, and the moths frequently mimic protected species of other families. This sub-family contains a large

number of species, but is confined to the warmer regions of the East. The third sub-family, *Phaudinæ*, consists of a number of small moths from India and Africa. The scales on the wings are imperfect, and the hind-wings are often reduced to a long slender tail. The mouth-parts are absent.

The eggs are laid singly or in batches on the food-plant, usually on the under-side of the leaf. They are flattened, slightly oval, and pale in colour. The larvæ are short and stout, being thickest in the centre. Usually they are of dingy colours, and are sparsely covered with short hairs. Their legs and sucker feet are small and their movements sluggish. The pupa is soft and black, and is capable of more movement than is usual among *Lepidoptera*. It is enclosed in a hard silken cocoon, which is usually attached to the food-plant and from which it wriggles out before the emergence of the moth. Hibernation as a rule takes place as a partially grown larva.

Zygænids are not of great economic importance; a few species, however, are pests, the most important being those which attack tea in India and Ceylon. These pests are known as Red Slug caterpillars and belong to the genus *Heterusia*. The suggested remedies are the hand collection of the adults and larvæ, and the segregation of infected blocks by means of wood-ash rings placed round the trees.

Brachartona catoxantha occasionally becomes a serious pest of coconuts in Malay. This pest will produce five broods in a season, so it is important to deal effectively with it on its first appearance. The remedies suggested are the hand collection of the eggs and of the adults, and a kerosene-emulsion spray for the larvæ.

Callidulidæ.

Hind-wing with vein 8 curved, with a precostal spur, and approximating to, or anastomosing with 7, or connected to it by a bar; vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum absent or rudimentary.

This is a small family of some fifty species, which are found in the Malay Archipelago and in Eastern India. The moths

are of medium size and slender build; they are day-flying and in appearance resemble butterflies. The antennæ are of medium length, and simple; the palps are long. In most cases the frenulum is absent, but in a few species it is present in a rudimentary condition. Nothing is known of the life-history of the members of this family. They are of no economic importance.

Drepanidæ (*Drepanulidæ*).

Hook-tips.

Hind-wing with vein 8 curved and approximating to or anastomosing with 7 or connected to it by a bar; no precostal spur; vein 1a absent or reduced, vein 1c absent; fore-wing with vein 5 nearer 4 than 6; frenulum present; proboscis aborted. Larva without anal claspers.

This family contains about 150 species, which are widely distributed throughout the world, but are particularly characteristic of sub-tropical forest areas. In Britain there are six species.

The moths are small or of medium size with slender bodies and large wings. Frequently the apices of the fore-wings are pointed and curved downwards, which gives to the moths their English name of Hook-tips. There is considerable variety in the coloration, shades of brown with black markings being the commonest form. Not infrequently the scales are imperfectly developed. The antennæ are of moderate length and sometimes pectinate in the male. The proboscis is aborted. The moths fly by night, the flight being rapid and erratic: they usually prefer wooded or forest districts. They are attracted to light.

The eggs are oval and are laid singly or in small batches on the food-plant, which is usually the foliage of trees. The larvæ are peculiar, the anal claspers being absent and the body terminating in a pointed process. They are destitute of hairs, but frequently bristle-bearing processes are present on the segments. The pupa is dark brown and is enclosed in a silken cocoon spun up in the foliage of the food-plant.

Hibernation usually occurs as a pupa in the cocoon, which generally drops off with the leaves to which it is attached, and remains during the winter on the ground.

The family has no economic importance.

Thyrididæ.

Hind-wing with vein 8 curved and approximating to or anastomosing with 7, or connected to it by a bar; no precostal spur; vein 1a reaching tornus; vein 1c absent; fore-wing vein 5 nearer 4 than 6; frenulum present.

This is a small family, but has a wide distribution in tropical and sub-tropical regions. There are no British species. The moths are small to medium-sized, and vary considerable in colour and form. As a rule they are slender insects, and many have hyaline patches on the wings. The antennæ are of moderate length and are not pectinate: the palpi are slender and upturned.

Little is known of the life-history. The larvæ that have been described resemble those of the *Pyralidæ*, having few hairs and five pairs of sucker feet. Many are internal feeders, boring in stems or roots. The family has no economic importance.

Pyralidæ.

Hind-wing with vein 8 approximating to or anastomosing with 7; vein 1c present; labial and maxillary palps usually well developed; proboscis present or absent.

This family contains an enormous number of species. Everywhere abundant, they are more characteristic of tropical than of temperate regions: in Britain there are 153 species.

The moths are usually small, few attaining a wing-span of more than an inch and a half. The colours are varied, but dull browns or greys are the most frequent. Pyralids as a rule are slightly built moths, with slender bodies, long narrow wings without fringes, and long thin legs. The antennæ are simple—sometimes ciliate and more rarely pectinate in the

males. The palps are well developed : the proboscis small and often absent. There is no general rule for sex determination. The colours, as a rule, are similar in the sexes, but the males may be distinguished sometimes by the character of the antennæ, by tufts on the wings or legs, or by their size. Usually the moths are night-flying and will come to light : they rest during the day-time with wings wrapped round or crossed flat over the body. The moths of one genus, *Acentropus*, are aquatic : entirely so in the female and partially so in the male. The males fly feebly over water ; the females, whose wings are reduced or absent, come to the surface for coupling and take the males down with them.

The life-history, except as regards the food habits of the larvæ, is fairly uniform. The eggs are round or oval, flat and scale-like, and are deposited singly or in batches on the food-plant, in a few cases the batches being covered with scales or hairs from the anal tuft of the female. The larvæ are elongated and cylindrical, usually greyish in colour, and with few hairs. There are five pairs of sucker feet on which the hooks are arranged in a circle. The larvæ usually feed in concealment : when disturbed they can move very rapidly, either forwards or backwards. The larval habits are very diverse. Many web leaves, others bore in stems or roots, a few are aquatic, while others again live in grain or flour, and some feed on the wax in beehives. Most frequently the pupa is chestnut brown, and capable of slight movement. It is enclosed in a silken cocoon, from which it is not protruded at the emergence of the moth. Hibernation usually takes place as a fully fed larva.

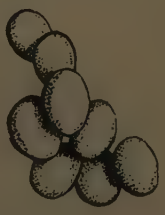


Fig. 133.— Eggs [of *Pionea forficalis*. (× 15.)

The family contains many pests, the most destructive being the stem-borers. The more important harmful species are mentioned under their respective sub-families. There is no uniform classification of the family. Meyrick in his group *Pyralidina* recognizes nine families, including three, the *Thyrididæ*, the *Orneodidæ*, and the *Pterophoridæ*, which are here treated separately.

Phycitinæ (=*Phycitidæ*, Meyr).

These are small moths with narrow wings, usually grey in colour, which are wrapped tightly round the body when at rest. The proboscis is well developed and the antennæ of the male are often dilated at the base. *Ephestia kühniella*, the Mediterranean flour moth, is a member of this group. It feeds on flour, biscuits, and other farinaceous products and causes great loss and damage in flour mills and bakeries, both in Europe and in America.

Galleriinæ (=*Galleriadæ*, Meyr).

This is a small sub-family, but with a very wide distribution. The moths are of moderate size, with a short proboscis and filiform maxillary palps: they are nocturnal in habit. The larvæ feed in concealment, and produce large quantities of silk, spinning webs and galleries where they feed, and pupating in a firm cocoon. The larvæ of several species live in the hives of bees, feeding on the wax, one in particular, *Galleria mellonella*, causing considerable damage.

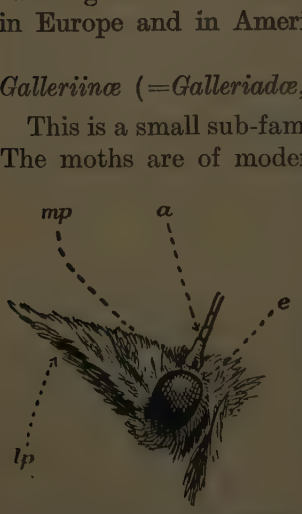


FIG. 134.—Head of a Crambid Moth (Fam. *Pyralidæ*).
a = antenna. *e* = eye. *mp* = maxillary palp. *lp* = labial palp.

Crambinæ (= *Crambidæ*, Meyr) Grass Moths.

This is a large sub-family, particularly in temperate regions. The moths are of moderate size with long narrow fore-wings. The maxillary palpi are triangular and heavily scaled, and give the head of the moth a pointed appearance. The proboscis is well developed. The moths fly at dusk, resting during the day in an upright position on grass stems, with the wings closely folded round the body. The larvæ feed on grass stems or roots, either boring into them or living in silken galleries at or near the ground level. Pupation takes place in the larval galleries.

Many of the notorious moth borers of sugar cane belong to this group. The most important are species of *Diatræa* and *Chilo*, *Diatræa saccharalis* in the West Indies and in North

America, *D. lineolata* in South America, *D. striatalis* and *Chilo infuscatellus* in Java, and *Chilo simplex* in India. These moths lay their eggs in masses on the cane leaves: the larvæ bore down the stem, and cause immense loss. The eggs are largely attacked by hymenopterous parasites, and egg masses should be collected, but not destroyed until any parasites that may be present have emerged. Further control measures are the use of light traps for the adults, and the destruction of young diseased cane. *D. saccharalis* and *C. simplex* also attack maize. *Chilo plejadellus* is a similar pest, that attacks rice in the United States.

Schœnobiinæ (= Part of *Pyraustidæ*, Meyr).

A small sub-family of moderate-sized moths, with the proboscis reduced or absent and the palpi rather short. This group contains the aquatic genus *Acentropus*, which has been already referred to: the larvæ of the remaining forms bore in the stems of grasses, several attacking sugar cane. The most important of these are *Scirpophaga auriflua* from India and Java, and *S. monostigma* from India. The eggs are laid in hair-covered clusters on the leaves: the larvæ work down to the base of the leaf-cluster and destroy the apical bud, and thence into the stem. The control measures adopted are similar to those used against *Crambinæ*. *Schœnobius bipunctifer* is a similar moth, which attacks rice in India. The egg masses are placed on the leaves and the larvæ bore down the stems, causing them to wither. All stubble should be ploughed in or burnt, in order to destroy the resting larvæ: if possible, the egg masses should be collected.

Hydrocampinæ (= Part of *Pyraustidæ*, Meyr).

These are slender moths, with long narrow wings and long legs. Many of the larvæ are aquatic, breathing by means of gills or breathing air at the surface. *Nymphula depunctalis*, the Rice Case Worm of India and Java, is destructive to the foliage of that crop. The eggs are laid on the leaves, and the larva forms a case from a rolled leaf, in which it can live either in air or in water. It pupates in a webbed-up leaf.

Pyraustinæ (= Remainder of *Pyraustidæ*, Meyr).

This is a very large sub-family, common everywhere, but particularly so in the tropics. The moths are of small to moderate size, the wings neither very long nor narrow. Most of the species fly at dusk and are attracted to light. The majority of the larvæ are leaf-webbers, but some few live openly on the plant and others bore in stems. The most important pest in this group is probably *Sylepta derogata*, the leaf-roller of cotton, which occurs in India, in Africa, and in Java. The eggs are laid on the leaves or shoots, and the larvæ feed on the leaves, rolling them by means of silken threads. The larvæ pupate in the foliage or in the soil. Hibernation, however, which they undergo when fully fed, always takes place in the ground. Alternative food-plants, of which there are many in the order *Malvaceæ*, should be controlled; other measures adopted are arsenical spraying, hand collection of the rolled leaves, and the ploughing up of the ground during the period of hibernation. *Maruca testulalis* is a widespread tropical pest of pulses, particularly pigeon pea. The moth is of moderate size, with large hyaline patches on the hind-wings. The larva attacks the pods of the crop, eating through them from end to end. *Dichocrocis punctiferalis* causes much damage to castor in India, boring in the stems and capsules: it also attacks cacao in Ceylon. Two species of this group attack rubber, feeding on the foliage, but neither of them are serious pests. They are *Caprinia conchylalis*, from Malay and Ceylon, and *Glyphodes ocellatella* from W. Africa. Probably the most serious pest in this group is *Pyrausta nubilalis*, the European corn-stalk borer. This is a cosmopolitan insect, which attacks maize, millet, hemp, and other crops. It is especially destructive to maize in the United States and in Canada, where it has only recently been introduced. It spends the whole of its larval and pupal life in the stems, hibernating there as a larva.

Pyralinæ (=Pyralididæ, Meyr).

This sub-family includes a large number of species, principally from the tropics. The moths are rather small, with long, narrow fore-wings. The larvæ are slender, and feed in silken webs

on dry or decaying vegetable matter. *Pyralis farinalis* is a cosmopolitan insect which is a minor household pest, feeding on flour, oatmeal, and similar substances.

Orneodidæ (*Alucitidæ*).

The fore-wing divided into six distinct plumes.

This family consists of about sixty species only, which are nearly all placed in the genus *Orneodes*. They are, however, widely distributed throughout the world. There is one British species, *Orneodes hexadactyla*.

The moths are of small to moderate size, and are easily recognizable by the division of both fore- and hind-wings into six plumes. The antennæ are of moderate length and are very slightly ciliate in the male: the proboscis is well developed. The moths fly at dusk, and are attracted to light. The larvæ are almost smooth, with few hairs and five pairs of sucker feet. They feed openly on the food-plant, many species consuming flower-buds. Pupation takes place in a silken cocoon. The British species passes the winter as an imago.

The family has no economic importance.

Pterophoridæ.

Plume moths.

Fore-wings narrow and divided into two, three, or four narrow lobes; hind-wings of one, two, or three lobes.

This family includes a fair number of species, and is widely distributed both in temperate and in tropical regions: nowhere, however, is it very conspicuous. There are thirty-one British species. The moths are small and slender, with long narrow wings, which, except in the genus *Agdistis*, are divided up into a number of plumes. The proboscis is well developed and the maxillary palpi are absent. The antennæ are of moderate length, slightly ciliate in the male. The legs are long and extremely slender, with conspicuous spurs. The colours are usually pale, buff, brown or greyish white being the commonest,

without definite patterns. The moths as a rule fly at dusk: they rest during the day with wings and legs outstretched.

The eggs are oval and smooth, but not flat; they are laid singly on the food-plant. The larvæ are short and of a distinct oval shape, with five pairs of sucker feet. They are usually cryptically coloured in grey or green, and, to a greater or less extent, clothed in hairs and spines, which radiate from slight protuberances throughout the length of the body. The larva is slow-moving and feeds openly on the food-plant. The pupa is soft and hairy and is usually attached to the food-plant by the cremaster; its colours are similar to those of the larva. Sometimes a slight silken cocoon is formed. Hibernation occurs in all stages, but usually as a larva or pupa.

The economic importance of the family is very slight. One or two species are pests on tropical pulses, the chief offender being *Exelastis atomosa* in India. The larvæ of this species feed on the pods of pigeon pea, biting holes in the pod and consuming the seeds from outside. The pupa is placed on the pod, fixed to it by the cremaster and a flimsy network of silk. The damage done by this pest is sometimes considerable.

The family is described by Meyrick in *Genera Insectorum*, Fasc. 100 (1910).

Sesiidæ (*Ægeriidæ*).

Clearwings.

Hind-wing with vein 8 absent; vein 1c present; proboscis small or rudimentary. Larva boring in the stems or roots of plants and pupating in the bore.

This family consists of small to medium-sized moths, with long, narrow, and usually hyaline wings. The body is long and slender, often with red or yellow markings, and not infrequently with an anal tuft of hairs. The antennæ are fairly long, and are thickened towards the tip. The legs are often heavily tufted with hairs. Sesiids are very active on the wing, and fly by day, preferring the hottest sunshine; but they are inconspicuous and not often observed. They are stated to mimic *Hymenoptera*, but probably true mimicry occurs in only a few species.

The distribution of the group is mainly temperate: there

are a large number of species, of which fourteen are British.

The eggs are usually laid singly on the bark of the food-plant. The caterpillar is white and elongate, with five pairs of sucker feet. It bores in the stems or roots of its food-plant, the plants attacked being very diverse. The pupa, which is generally enclosed in a slight cocoon of silk and wood-chips inside the bore, is furnished with spines on the abdominal rings, and has more power of movement than is usual in *Lepidoptera*. Hibernation usually takes place as a larva; frequently the life-history occupies two or more years.

Several of the Sesiids are pests, but none are of first-class importance. The best-known species in this country is *Sesia* (*Ægeria*) *tipuliformis*, which attacks the stems of currant. In America, the most important is probably *Ægeria* (*Sanninoidea*) *exitiosa*, which attacks the trunks of peach trees close to the ground, and causes much damage.

Tortricidæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; middle spurs of hind tibiæ well developed; palpi obtuse; proboscis and frenulum present. Larvæ living in concealment.

This is a very large family, with a very wide distribution: it is, however, more characteristic of temperate than of tropical regions. There are 330 British species. The family is subdivided into several sub-families which are ranked as families by many authorities. Meyrick recognizes four families, grouped in the super-family *Tortricina*.

The moths are of small size, with densely scaled wings usually of dull colours. The fore-wings, as a rule, exhibit brown markings, the hind-wings being without a pattern. The fore-wings are long and frequently have a characteristic appearance due to a hump on the costal margin. In rest, the wings are wrapped round the body. The antennæ are of moderate length and the proboscis is present. The majority of Tortricids fly at dusk with a rapid, darting flight: in the day-time they rest on tree trunks, the under-sides of leaves, and in other suitable places, and are very inconspicuous.

The eggs are very small, flat and scale-like. They are usually whitish in colour, and are deposited singly or occasionally in clusters on the food-plant. The larvæ are small but elongate, with few hairs, and live in concealment. The head is usually black, and in most cases there is a black bar-shaped chitinous plate on the first thoracic segment. The general colour is usually greyish-white, but sometimes green or pinkish. There are five pairs of sucker feet, the hooks on which are arranged in a circle. The majority of the larvæ feed in rolled or webbed-together leaves, but quite a number burrow into fruit, flower-heads, or stems. The pupa is usually chestnut brown in colour. It is enclosed in a tight silken cocoon from which the pupa is protruded just before the emergence of the moth. Pupation takes place amongst the foliage, in crevices in the bark of the food-plant, or on or just beneath the surface of the soil. The insect hibernates, as a rule, in the cocoon, either as a fully fed larva or in the pupal state.

Although less destructive as a group than the *Pyralidæ*, yet the *Tortricidæ* contain some very serious pests. These may roughly be divided into two classes—those which tunnel into the fruit, bud, or other part of the plant, and those which roll and consume the foliage. Of the first group, by far the most important is the notorious Codlin Moth, *Cydia* (*Carpocapsa*) *pomonella*, which annually causes immense damage to apples and pears in every fruit-producing country of the world. The larva tunnels into the fruit, entering it at the calyx if young, or at the side if fully formed, and feeds inside. When full grown it leaves the fruit by a fresh tunnel and pupates in the soil or, more usually, in some crevice of the bark. The number of broods in the year depends on the climate, varying from one to four. The most effective remedies are arsenical spraying before the calyx of the fruit closes, and again in summer if there is a second brood; and banding the trunks with hay or sacking, to trap pupating larvæ. Other pests of this class are *Laspeyresia* (*Semasia*) *nigricana*, which in Europe and in America attacks peas in the pod; *Eucelis* (*Epinotia*) *funebrana*, which attacks plums in Europe. Another serious pest is *Eudemis* (*Polychrosis*) *botrana* in Europe, and an allied species *E. viteana* in America, which attack the fruit of the grape. Very severe damage is caused by these

pests, one larva being able to destroy a whole bunch of grapes. Control by fungi and by insecticides is being attempted in America. The Apple Bud Moth, *Tmetocera ocellana*, which as its name implies bites into the buds of apple and other fruit, is a serious pest in Europe, and allied species cause great damage in America. The buds should be thoroughly sprayed with lead arsenate before they open, a coarse driving spray being employed.

The leaf-rolling pests are not nearly so serious as those previously mentioned. In most cases, they can be easily dealt with by a poison spray. *Capua coffearia*, which attacks tea in Ceylon, cannot be controlled in this manner. It is dealt with by the collection of egg-masses, and by destroying the imagines by means of the Vermorel light trap. *Conchylis epilinana* attacks the foliage of flax in Europe, and in addition sometimes tunnels into the unripe capsule. *Ancylis comptana* attacks strawberry in America, where it sometimes causes serious loss. It occurs in Europe, but is not a serious pest. Many other species attack various fruit trees, especially the apple; but these are effectively controlled by the spraying for Winter Moth.

The sub-family *Tortricinæ* is monographed by Meyrick in *Genera Insectorum*, Fasc. 149 (1913).

Tineidæ.

Hind-wing with vein 8 free or connected to the cell by a bar; vein 1c present; palpi acute; tibiæ with all the spurs developed.

This is a very large family, probably containing more species than any other. It has a world-wide distribution, its members being abundant both in tropical and in temperate regions. There are 700 British species. The moths are small, some excessively so. The wings are narrow, with a wide fringe of scales; in some cases the number of nervures is reduced. The majority of species are night-flying with dull colours, the fore-wings usually with vague markings, the hind-wings without a pattern. A few species are diurnal and are brightly coloured. When at rest, the wings are usually folded flat over the body

or held outstretched, and are not wrapped round the abdomen. The antennæ are commonly simple, and of moderate length; as a rule, they are rather longer than those of the Pyralids, and in some cases, such as *Adela*, they are proportionately very long.

The eggs are very small, round or oval, and flattened. As a rule, they have reticulate markings on the upper surface, and are deposited singly on the food material. The larva is elongate and slender, with few hairs: the most usual colour is grey, often dotted with black. There are five pairs of sucker feet, on which the hooks, as in the *Pyralidæ* and the *Tortricidæ*, are arranged in a circle. The food habits of the larva are very diverse. Many web leaves, some bore in stems, or under bark, or mine leaves or shoots, while others again feed in the seed capsules of plants. A few species are household pests, consuming cloth and other material, while one or two are carnivorous and feed on scale insects. The larvæ of many species construct cases of silk and fragments of their food material. They pass the whole of their larval life in these cases, carrying them about when they move. The pupa is usually brown, and is capable of movement of some of the abdominal segments, the number varying in different species. It is enclosed in a cocoon of silk, from which it is sometimes protruded on emergence. Hibernation takes place usually as a fully fed larva, but sometimes in the pupal stage.

FIG. 135.—Head of Tineid.
a = antenna. *e* = eye. *mp* = maxillary palps. *p* = proboscis.

Tineidæ are divided into a number of sub-families, but there is no uniform classification. Only those groups that contain economically important species are here mentioned. Meyrick recognizes six families in the group *Tineina*, of which one, the *Ægeriadæ* (= *Sesiidæ*) is here treated as distinct. The *Tineidæ* contain a large number of pests, ranking alongside *Noctuidæ* and *Pyralidæ* as a destructive group.

Gelechiinæ (*Gelechiadæ*, Meyr).

A large group with a world-wide distribution. They are small moths, with a well-developed proboscis and short maxillary palps. The hind-wings are of peculiar shape, being pointed at the apex. The pupa is not protruded from the cocoon at emergence. This group contains *Gelechia* (*Pectenophora*) *gossypiella*, the Pink Bollworm of cotton, one of the most destructive of insect pests. It occurs in India, Egypt, Sudan, America, and the West Indies, but is most serious in Egypt, where 17 per cent. of the cotton crop is annually destroyed by its ravages. In India it is probably controlled by *Rhogas* parasites. It has been recently introduced into America, and strenuous efforts are being made to confine it to a relatively small area. The larva bores into the boll and eats out the seed, hibernating inside the seed. All waste bolls are collected and burnt, while seed not wanted for cattle food is heated to a temperature of 55° C., which is sufficient to kill the larvæ which may be hibernating without destroying the germinating power of the seed.

Gelechia (*Lita*) *ocellatella* attacks beet in Europe, but is not a serious pest except in France. All parts of the plant are attacked, but the main damage is caused by the larva boring in the root.

Phthorimæa operculella (= *Lita solanella*) is a first-class pest of potato. It occurs in the Mediterranean region, in India, and in America. It attacks both the foliage and the tubers, mining in the leaves or boring into the potatoes themselves. It will also attack stored potatoes, and it is here that its most serious damage is caused, as seed-potatoes are frequently destroyed.

Gnorimoschema (*Phthorimæa*) *heliopa* is the stem-borer of tobacco in India and in S. Africa. The eggs are laid on the leaves, and the larva tunnels down the midrib into the stem, causing it to swell. It pupates inside the tunnel. The pest attacks seedlings chiefly, and these should be carefully watched and destroyed if infected.

Anacampsis nerteria attacks ground-nut in southern India and in Ceylon, causing severe damage. The larva is a leaf-miner, and pupates amongst the foliage in silken webbing.

Œcophorinæ (*Œcophoridæ*, Meyr).

This is a widespread group, but is predominant in Australia, where nearly 1,000 species have been described. The larvæ feed principally among spun leaves or in decayed wood. A few are carnivorous. The pupa is not protruded from the cocoon on emergence of the moth. One species of the sub-family *Hypatima pulverea* feeds on lac in India, consuming not only the insects, but the dry shellac after it has been cut.

Plutellinæ (*Plutellidæ*, Meyr).

A sub-family of moderate size, with a wide distribution. The larva is usually a leaf-webber. As a rule, the pupa is not protruded from the cocoon on emergence. The most important pest in this group is the Diamond Back Moth, *Plutella maculipennis*, which attacks cruciferous crops. It is a cosmopolitan species, seeming to flourish equally well in all climates, and sometimes becomes so abundant as to cause serious loss.

Prays oleellus is a pest of olives, in Europe, attacking the foliage; it is not very serious.

Tineinæ (*Tineidæ*, Meyr).

This is a very large group, and is equally common in all regions. The moths are usually small, and in some cases the veins are reduced in number. The larvæ, as a rule, are leaf-miners or case-bearers. The pupa often has the abdominal segments very mobile, and is usually protruded from the cocoon in emergence. The most important pests in this sub-family are the clothes moths, of which there are several species, the most important being *Tinea pellioniella*, whose larva is a case bearer, *Trichophaga tapetzella*, the larva of which forms silken galleries over the cloth, and *Tineola biselliella*, whose larva forms neither case nor galleries. All these species have a world-wide distribution, probably due to artificial introduction, and do enormous damage to cloth, furs, feathers, and similar material. A simple household insecticide, such as naphthaline, is usually sufficient to expel the pest.

Oinophila v-flavum is a minor household pest, which normally feeds on moulds on the walls of cellars, but occasionally bores into the corks of wine bottles.

Crypsithyris longicornis is a case-bearing insect from India, where it lives on whitewashed walls, presumably deriving its nourishment from the size in the whitewash.

Several of the sub-families of *Tineidæ* have been monographed by Meyrick in *Genera Insectorum*, Fasc. 128, 133 (1912), and 164 and 165 (1914).

Hepialidæ.

Swifts.

Both wings with twelve veins, the cell of the hind-wing emitting more than six; jugum present; maxillary palpi and tibial spurs absent; proboscis aborted.

The *Hepialidæ* are a widely distributed family, though the number of known species is small, only about 170 having been recorded. It is in Australia that the family appears to attain its highest development, where sixty to seventy forms occur. In Britain we have but five species. Both in size and in coloration the Hepialids exhibit great diversity, ranging from small sombre moths to the giant *Zelotypia* (*Leto*) *stacyi* of Australia, with a wing-span of nearly eight inches. Fore- and hind-wings are similar: both are long and narrow with imperfect scales and twelve nervures. The body is long and narrow; the proboscis is absent and the labial palps are poorly developed. The antennæ are filiform and are very short.

The eggs are round and smooth, and, as a rule, are dropped by the female when flying over the food-plant. A very large number, sometimes several thousand, is laid by each female. The larvæ are elongate, whitish and sparsely clothed in hairs. They feed underground on the roots of plants, or burrow in woody stems. Several years are frequently passed in the larval stage. The pupa is elongated, almost cylindrical, and soft. Rings of hooks are situate on the abdominal segments, and the pupa is capable of considerable movement. Pupation takes place in the tunnel or in the soil in a slight cocoon: the pupa wriggles free of the cocoon, and often to the surface, before the emergence of the moth. Hibernation usually takes place as a partially fed larva.

Hepialids are of very slight economic importance. Two species have been recorded as minor pests in this country: *Hepialus humuli*, which attacks the roots of hop, and *H. lupulinus*, which feeds on the roots of strawberry.

Micropterygidæ.

Both wings with twelve veins, the cell of the hind-wings emitting more than 6. Proboscis short or aborted. Mandibles sometimes present. Maxillary palpi well developed. Jugum present.

This family consists of a number of very small moths, which differ largely from all other *Lepidoptera* and vary considerably among themselves. They are of metallic coloration, with long antennæ, and fly in bright sunlight. In some cases there are well-developed mandibles, in others a short proboscis. The mandibulate forms are pollen-feeding. In some species the females are provided with a cutting ovipositor, and lay the eggs inside the tissues of the food-plant.

Micropterygids are essentially a temperate group: they have been recorded from Europe, Asia, America, and New Zealand. There are thirteen British species.

The eggs are laid on, or in, the tissues of the food-plant. The larvæ are of two types: the first (*Eriocrania*) forms a blotched mine in the leaf of the food-plant, and has no legs or sucker feet. The second type of larva (*Micropteryx*) feeds openly on damp moss. It possesses three pairs of legs and eight pairs of abdominal feet, and a trilobed anal clasper. The antennæ are long, and the body bears rows of ball-like protuberances. The pupa is enclosed in a cocoon of silk, and is placed on or underneath the surface of the soil. In some cases (*Eriocrania*) the appendages are free, and the pupa is provided with a pair of large mandibles, which are shed on emergence.

Micropterygidæ are of no economic importance.

The family has been described by Meyrick in *Genera Insectorum*, Fasc. 132 (1912).

DIPTERA

Flies.

One pair of wings only, attached to the mesothorax; a pair of balancing organs (halteres) attached to the metathorax. Mouth-parts suctorial and sometimes adapted for piercing. Larvæ legless, the pupa either coarctate or obtect. Metamorphosis complete.

The *Diptera* constitute that group of insects to which the term "flies" should be confined. They are on the whole small insects, the *Tipulidæ*, *Tabanidæ*, *Asilidæ*, and *Mydaidæ* containing the largest forms, the last-named family having the largest known fly (*Mydas* sp.). *Mydas* is a South American fly, and is over 2 inches long, with a wing-span of four and a half inches. Many families contain minute forms, and these mostly belong to the *Orthorrhapha*. Insects of this order are found in the hottest and coldest climates, and have been taken all over the world.

The characters given are sufficient to place an insect definitely in or out of the *Diptera*. There are, however, exceptions to three of the above characters. A certain number of forms are entirely wingless, or have only vestiges of wings remaining. Bezzi (1922) gives the following numbers of species in this category: *Nemocera*—140; *Brachycera*—12; *Cyclorrhapha*—232. Secondly, according to Wasmann, *Termitoxenia* has no free larval or pupal stage, but gives birth to adults. Thirdly, in a few forms the mouth-parts may be vestigial or absent.

Flies, as a rule, are strong and powerful fliers. In a few families is to be found a specialized system of flight in which a swarm dances together in an apparently aimless fashion. Such swarms are usually confined to one sex, and are to be found among the "gnat" tribe, the *Culicidæ*, *Dixidæ*, *Chironomidæ*, and in the *Empidæ*. Others, notably the *Syrphidæ*, have a fondness for maintaining themselves at some fixed point above the ground, the wings moving with great rapidity the while.

Colour in *Diptera* is on the dull side. Dull grey or brown is very common, often with patches or stripes, while many are uniformly black, as regards the body. The wings are usually

transparent, but may have speckles, dusky markings, patches, or bands of dark colour on them. Where bright colouring is found, it is usually a scheme of black and yellow banding, as is found in the *Syrphidæ*, *Conopidæ*, and *Oscinidæ*. Where metallic colouring appears, as in the *Dolichopodidæ* and in the Muscoid group, it is either green or dark blue. Red is never found except in the eyes. The sexes are, almost without exception, alike in coloration, but there are a few exceptions amongst the *Bibionidæ*, *Tabanidæ*, *Cordyluridæ*, and *Muscidæ*.

Mimicry is found in the *Syrphidæ*, *Mydaidæ*, *Asilidæ*, and *Conopidæ*, some of which bear marked resemblance to wasps and bees in coloration, shape, and size. Indeed, in the tropics it is sometimes impossible to tell the difference between some species of the *Conopidæ* and the *Sphegidæ* and *Vespidæ*, while they are on the wing. Adult flies need a warm temperature for active flight or they become torpid ; many perish of cold in the winter. Their food consists of pollen, honey, plant juices or the nutritious liquid of moist organic detritus. Some are predaceous on other insects, from which they suck the body juices, and some suck the blood of higher vertebrates. In the *Orthorrhapha* blood-sucking is confined to the female sex : in the *Cyclorrhapha* both sexes indulge in this unpleasant habit.

The *Diptera* are separated into two big groups, corresponding to the way in which the pupa or pupa-case splits when the adult insect emerges. Those families in which there is a split more or less straight down the back of the thorax are grouped together as *Orthorrhapha* (i.e. "straight crack") while those in which the split runs round the end of the pupa-case are called *Cyclorrhapha* (i.e. "round crack").

Of course it is often impossible to see the way in which any particular fly escapes from the pupa, and these divisions would be useless were they not also indicated by other characters more easily observed. The Orthorrhaphous pupa itself differs from the Cyclorrhaphous in that the latter is enclosed in the last larval skin, which remains round it as a protecting case, the pupa and its case together being called a "puparium." In the *Orthorrhapha*, with few exceptions (e.g. the family *Stratiomyidæ*), we find, on the other hand, that the last larval skin is completely shed and cast aside, leaving the pupa bare and unprotected ; in such pupa the limbs and general shape of the

future imago can be seen, while in the Cyclorrhaphous puparium all these details are completely concealed by the hardened and contracted larval skin which encloses the true pupa. This difference in the type of pupa is associated with a difference in the way the fly gets out of it: in the *Orthorrhapha* the splitting of the comparatively weak pupa skin is effected by what we may call "hunching the shoulders," and the top of the thorax is the part of the fly's body which is first exposed. The *Cyclorrhapha* employ a different method, perhaps owing to the less yielding nature of the hardened skin which surrounds the true pupa. In order to escape, the fly, instead of trying to crack this skin along the thorax, pushes out the end of it and emerges head-foremost. To push out the end it cannot use its feet and limbs, since these are confined mummy-like in the puparium, but it gets over the difficulty by the help of a very remarkable structure, in the shape of an expansible balloon arising from the head. When inflated with liquid from the body, this balloon (called a "ptilinum") pushes off the end of the puparium and releases the fly, whose escape is rendered easier from the shrinking of the body due to the absence therefrom of the liquid used to inflate the balloon. The ptilinum is afterwards deflated and disappears into the head, leaving the scar called the "frontal suture" as evidence of its existence. All flies with this frontal suture are *Cyclorrhapha*.

It should be noted that three families (*Platypezidæ*, *Pipunculidæ*, and the big family *Syrphidæ*) are included in the *Cyclorrhapha*, although they do not possess a frontal suture; they are therefore known as *Cyclorrhapha "Aschiza"* (i.e. without suture), being classed with the *Cyclorrhapha* because of the mode of splitting of the pupa-case as well as by the form of the antennæ and by their possessing a small but systematically important structure in the shape of a minute sclerite just above the base of the antennæ, called the frontal lunule, which is characteristic of *all* the *Cyclorrhapha*. Apart from these three families, the rest of the *Cyclorrhapha* consists of a vast number of species possessing both lunule and suture, and hence known as *Cyclorrhapha "Schizophora"* (i.e. possessing suture). House-flies and blue-bottles belong to this group. The *Cyclorrhapha* as a whole are also distinguished by their antennæ having not more than three joints, the third joint

showing no signs of being segmented or made up of more than one piece, while it bears on its upper side an "arista" which is quite thin and hair-like and frequently plumose or pubescent. The palpi are unjointed. The *Cyclorrhapha* are thus divided into two groups, the *Aschiza* and the *Schizophora*. The *Orthorrhapha* are likewise divided, but here the division is based mainly on the structure of the antennæ. The first group, the *Orthorrhapha "Nemocera"* (i.e. "thread-horn") generally have four-jointed palpi and long antennæ, usually composed of a dozen or more similar freely-jointed segments, while the second group, the *Orthorrhapha Brachycera* (i.e. "short-horn") have palpi of not more than two joints, and short antennæ which show various grades between the many-jointed Nemocerous antennæ such as those of mosquitos or *Simulium*, and the simple, short, three-jointed antennæ of the *Cyclorrhapha*. From the Cyclorrhaphous antennæ those of the *Orthorrhapha Brachycera* differ in that they usually show pretty clearly that what may look like the third joint and its continuation (arista) is really made up of several joints or segments joined together. It may be noted that when, as in many *Brachycera*, the arista is thick and terminal, it is generally called a "style" to distinguish it from the very thin, usually dorsal, arista of the *Cyclorrhapha*.

The life-histories, while very various in detail, exhibit a general broad similarity. Eggs are laid in or close to the food necessary for the larvæ. The larvæ of the *Nemocera* are mostly aquatic, or inhabit wet places, the former usually developing into floating pupæ. Very few of the larvæ are predaceous, most of them being vegetarians or scavengers, and the imagines are in many cases blood-suckers (Mosquitos, Midges, Sandflies, and *Simulium*). One family, the *Cecidomyiidæ*, includes many gall-makers. The larvæ of the *Brachycera* are only occasionally semi-aquatic or aquatic (e.g. *Tabanidæ*, the horse-flies, and *Stratiomyidæ*), and are mostly either predaceous or parasitic on other insects; a few are scavengers. The adult Tabanids suck the blood of animals, several other families suck the juices of insects, while those flies which develop from parasitic larvæ generally frequent flowers and suck nectar.

In both the *Nemocera* and *Brachycera*, most of the larvæ

have a distinct and well-formed head, which is clearly separate from the thoracic segments.

The larvæ of *Aschiza* and *Schizophora* are of a different type, for in these the head is very small and either habitually retracted or poorly developed, without any neck or distinctly marked division from the thorax, while the jaws are generally represented by two small hooks which work up and down, and not horizontally as in many *Nemocera*. With the exception of some *Syrphidæ* we do not know of any predaceous larvæ in these groups ; a few are aquatic, a considerable number attack living plants, and a still larger proportion are scavengers or are parasitic on insects or mammals. Excluding the aquatic and some of the parasitic forms, the general appearance of the larva is much the same in the great majority of the species. The tail-end is thick and blunt, bearing two chitinized patches marking the openings of the posterior spiracles : from the tail the body tapers towards the head, which is quite small, eyeless, and furnished with a pair of downward-curving hooklets which serve as jaws. The adults are nearly all flower-flies, a few are predaceous, and there are a small number of species which suck blood.

If we except the Fleas, Mosquitos, Sandflies, and perhaps some Midges, we may say that no *Diptera* appear to be nocturnal. Excepting the predators and blood-suckers, the adults frequent either flowers or filth. Hibernation apparently takes place most often in the larval or pupal condition, but sufficient information on this point has not yet been accumulated ; some flies (e.g. Mosquitos) are known to hibernate as adults.

Not much is known about the past history of *Diptera*, but from the study of insects preserved in amber it appears that the oldest forms are among the *Nemocera*, and that the *Schizophora* are of much more recent development. Now if we compare these two groups we shall see that development has largely taken the form of reduction, shortening, and simplification of parts rather than the production of new ones. This does not apply to the ptilinum, which is an organ not possessed by any of the *Nemocera*, but it does apply especially to the antennæ, palpi, and venation. Figure 136 represents two antennæ of *Nemocera*, two of *Brachycera*, and one of *Aschiza* and *Schizo-*

phora. The possible course of development is clearly seen whereby a Nemocerous antenna might in course of time be modified into the compact three-jointed Muscid pattern (6). So also with the maxillary palpi (labial palpi are very rarely if ever, present); those of the *Nemocera* generally have four joints, the *Brachycera* two or one, the *Aschiza* and *Schizophora* always one only.

The question of venation is more complex; however, on

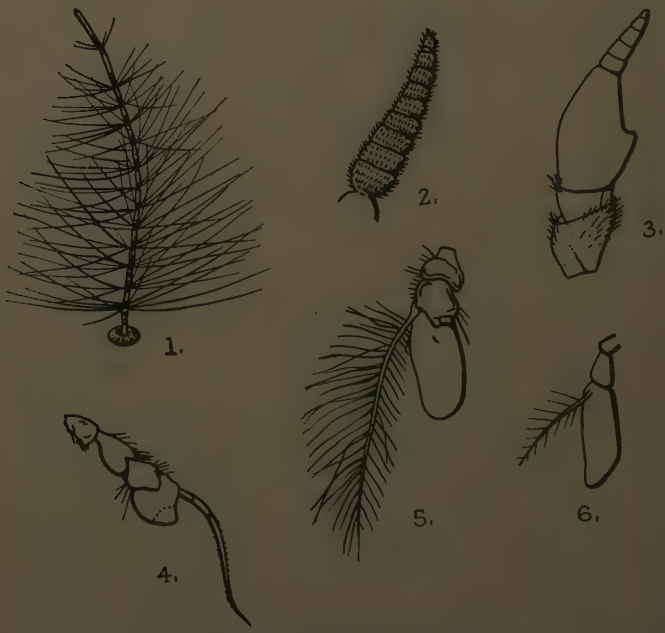


FIG. 136.—Antennæ of Diptera.
1. Culicid. 2. Simuliid. 3. Tabanid. 4. Dolichopodid. 5. Syrphid. 6. Muscid. (After Comstock and Sharp.)

comparing the wings of the *Nemocera*, *Brachycera*, *Aschiza* and *Schizophora*, it is clear that the main characteristic of the *Schizophora* is the comparatively few veins in the hinder part of the wing, and the closing up of the cells near the base (basal and anal). In the *Nemocera* the hind part of the wing has several veins, and the anal cell is large and open. In the *Brachycera* the anal cell shows signs of diminution, and may be

either narrowed at the margin or closed. In the *Aschiza* it is always closed, though often large, while in the *Schizophora* it is always closed and usually quite small. In this connection it should be pointed out that though what has just been said is true on the whole, yet indications of this line of development by reduction of wing-veins can also be traced in each of the four groups taken singly, more particularly among some of the smaller *Nemocera* and *Brachycera*, such as the *Chironomidæ*, some *Bibionidæ*, and especially *Simulium* in the former, and in the latter some *Stratiomyidæ*, *Cyrtidæ*, *Dolichopodidæ*, and especially *Phoridæ*. The same tendency towards simplification is met with in the larvæ. Speaking in a general way one may say that the oldest families of flies are those which have aquatic or semi-aquatic larvæ with distinct head and eyes. Such larvæ are the rule among *Nemocera*. Bibionid and Mycetophilid larvæ, though not aquatic, cannot endure drought. The gall-making *Cecidomyiidæ* are a much specialized family whose larvæ are in no way aquatic.

In the *Brachycera* there are a good number of this aquatic or semi-aquatic type among the more primitive families (*Leptidæ*, *Stratiomyidæ*, and *Tabanidæ*), but most Brachycerous larvæ (*Asilidæ*, *Therevidæ*, etc.) live on land, preying on such insects as are found in rather damp but not very wet places, such as rotting wood, bark, or in moss or earth. They are active with distinct heads, the eyes are present in some species and absent in others, and the antennæ are not so well developed as in Nemocerous larvæ. There also occur in this group a large number of parasitic larvæ (*Bombyliidæ*), but these, at any rate in their later stages, are almost incapable of motion and have no distinct head, jaws, eyes, or antennæ, though when newly hatched the larvæ may be very active. Among the *Aschiza*, there is a considerable variety in the form and habits of the larvæ; they may be scavengers, vegetarians, predators, parasites, or commensals, and there are a small number which are aquatic (e.g. genus *Eristalis* in family *Syrphidæ*), but in spite of this variety in their mode of life the head is never well developed, and the eyes and antennæ are either absent altogether or extremely small, the general shape approaching that of a "maggot." Much the same may be said of the larvæ of *Schizophora*, but in this group there is less

variety of habit. In the section containing what are probabl the older and less recently developed families (the " acalyptrat muscoids "), there are a few aquatic larvæ (e.g. *Ephydrida Sciomyzidæ*); and of the rest very few, if any, are truly pre daceous, and almost all feed on living plants, or are scavenger or parasites. Simplification of form has here been carried t an extreme, the head and sense organs being reduced to th lowest possible point. The probable reason of this extrem simplification lies in the shelter and protection which the larva habits ensure: living, as these larvæ do, either inside plants

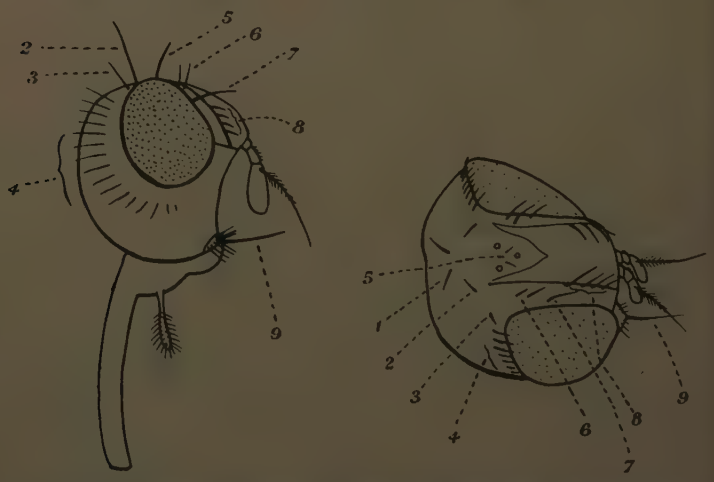


FIG. 137.—Diagram of Head of *Scatophaga stercoraria*, showing main bristles. Left figure—profile. Right figure—oblique plan.

1. Post-vertical. 2. Vertical (inner). 3. Vertical (outer). 4. Post-orbital. 5. Ocellar. 6. Fronto-orbital. 7. Cruciate. 8. Frontal. 9. Oral vibrissæ.

under dung and decaying matter, or as parasites in the bodies insects and other animals, they have little need of any organ except those which enable them to breathe, eat, and digest all else has tended to degenerate and disappear, leaving residue the typical maggot, a creature admirably adapted t succeed in its own simple way of life.

The head of a fly is as a rule spherical or hemispherical i shape, and may have bristles on the vertex, front, and cheek and round the oral margin. In some families the head, com pared with the thorax, is small and gives the flies a hunch

packed appearance. The eyes are often large and may occupy nearly all the surface of the head (e.g. *Pipunculidæ*). In a few families the eyes have facets of two sizes, a characteristic though, usually confined to the males. The eyes of the males are frequently closer together (sometimes touching, when they are known as "holoptic") than those of the females. This does not apply to the *Acalyptratæ*, where the eyes are "dichoptic" in both sexes. Ocelli are usually present on the upper part of the front, between the compound eyes; there are usually

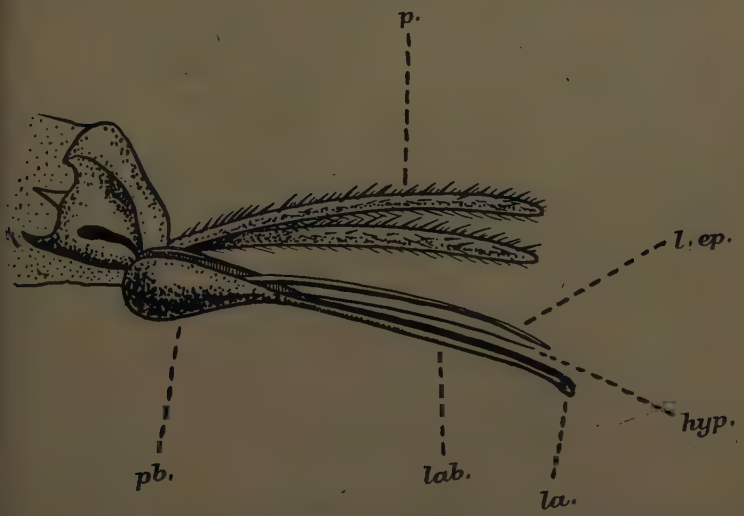


FIG. 138.—Mouth-parts of *Glossina submorsitans* (× 30) (slightly modified from Patton and Cragg).

p. = palpi. *l.ep.* = labrum and epipharynx. *lab.* = labium. *la.* = labella. *hyp.* = hypopharynx.

three, arranged in the form of a triangle: occasionally one may be absent, the two remaining being more widely separated and lying close to the eyes.

The mouth-parts may include all the structures found in the simpler insects, but formed for piercing, lapping, or sucking, or may have undergone a very extensive reduction. In the simpler types, as in the *Nemocera*, the labrum, with or without epipharynx, the maxillæ with palps, the labium with hypopharynx but without palps are present: in the types such as *Musca*, *Glossina*, *Stomoxys*, there is a disappearance of man-

dibles and maxillæ, the epipharynx and hypopharynx form the functional parts with the labium as a sheath and guide. In the latter the mouth-parts, if suctorial, depend on the conjunction of epipharynx and hypopharynx as a channel up which food is sucked, and the hypopharynx is usually the tubular piercing structure through which the secretion of the salivary gland is pumped into the host.

In all forms which are not blood-sucking, the labium alone becomes dilated at the apex either into a short broad hairy

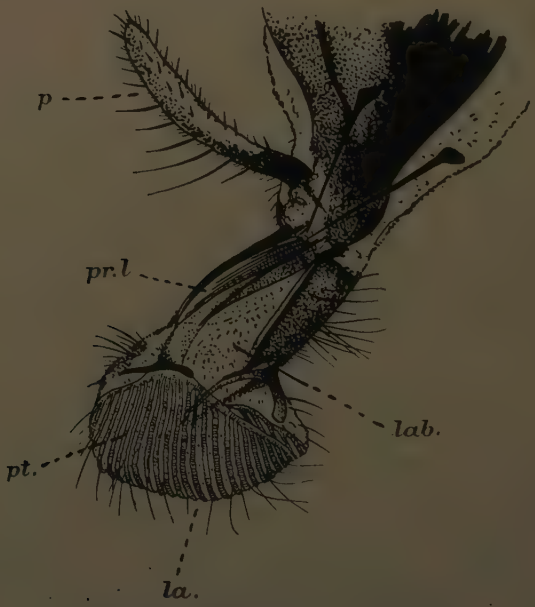


FIG. 139.—Mouth-parts of a Muscid.

p. = palp. *la.* = labella. *pt.* = pseudo-tracheæ. *lab.* = labium. *pr.l.* = prelabrum.

tongue, which functions as does that of a bee, or into two opposed lobes with a complicated series of channels kept open by chitinous rings which limit the size of the particles in the liquid passing along a channel. In such forms as *Musca*, the lobes at the apex of the mouth (the labella) act as squeezing organs (with a scraping action produced by teeth at the base of the lobes) and liquid passes along the channels to the centre, where it passes up the pharynx.

In all forms, there is a pharynx with muscles which acts as a

sucking pharynx to draw fluid up from the food channel: in the case of a direct blood-sucker such as *Culex*, the blood is drawn straight in between the epipharynx and hypopharynx, which themselves are embedded in the tissue of the host.

It is impossible in this place to give a structural account of the mouth-parts in detail: in the textbook of Patton and Cragg (1913) it occupies forty-seven pages with many plates, and this deals only with blood-sucking species and *Musca*. For our purpose there are simple mouth-parts, blood-sucking or lapping, with most of the parts of the normal mouth; there are greatly reduced piercing mouth-parts with practically only

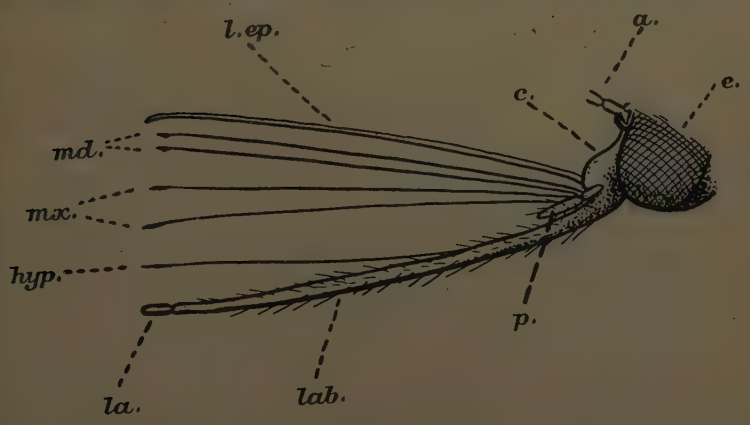


FIG. 140.—Mouth-parts of *Culex fatigans*. (× 30.) (Modified from Patton and Cragg.)

a. = antenna. *e.* = eye. *c.* = clypeus. *l.ep.* = labrum and epipharynx. *md.* = mandibles. *mx.* = maxillæ. *hyp.* = hypopharynx. *lab.* = labium. *la.* = labella.

the epipharynx, hypopharynx, labium, and palps; there are liquid-absorbing mouth-parts with mainly the developed labium, but sometimes also piercing parts; and there is, for instance, the extraordinary combination (*Pangonia*) of a long honey-lapping labium with short piercing organs. It may be noted that very little is known about the mouth-parts of *Nemocera* and *Brachycera*, except when these are blood-sucking.

A word should be said here about the breathing arrangements of Dipterous larvæ and pupæ. The devices and structures which they employ to obtain oxygen are extremely beautiful,

but so various that we cannot attempt any general account of them; the student will find a great deal of interesting information in Miall's *Aquatic Insects*, and further knowledge can be obtained from the nearest pond.

The typical respiratory system of the Dipterous larva consists of two big tracheal tubes running from tail to thorax, connected with each other by cross-tubes and having side branches to the lateral spiracles. There is a general tendency for these lateral spiracles to degenerate, so that breathing may be mainly or entirely carried on by the anterior (prothoracic) and posterior spiracles only; larvæ with this arrangement are called "amphi-

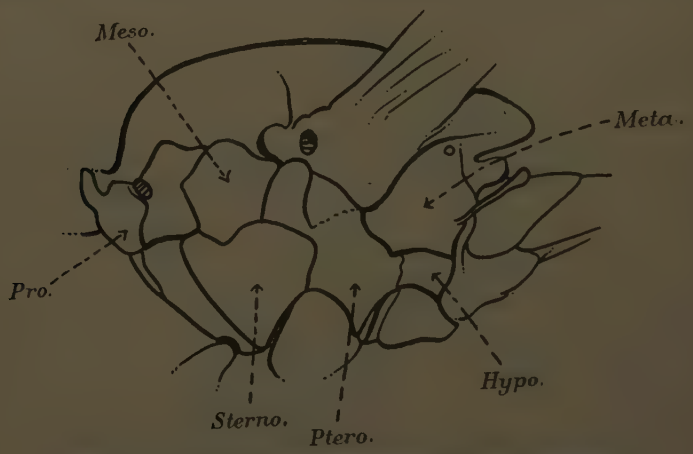


FIG. 141.—Pleural divisions of *Syrphus* (after Williston).

Pro. = propleura. *Meso.* = mesopleura. *Meta.* = metapleura. *Sterno.* = sternopleura. *Ptero.* = pteropleura. *Hypo.* = hypopleura.

pneustic;" in many larvæ, expecially in aquatic species, the posterior spiracles alone remain functional, and then the larvæ are called "metapneustic." In these aquatic forms respiration is often carried on in part by gill-processes, generally situated at the tail end of the body. Some parasitic larvæ (*Œstridæ*) are able to live for long periods in the body of their victim without air.

The thorax is very compact. Viewed from above, the mesonotum alone is visible, covering the whole thorax, except in the *Nemocera*, where usually a narrow pronotum can be seen. A "transverse suture" runs across the mesonotum in front of

the point of attachment of the wings; it is often incomplete in the middle. Another suture, behind the wings, also running transversely, cuts off a small portion of the mesonotum, the "scutellum." In the *Celyphidæ* the scutellum is enormously developed, so that it almost, or quite, covers the abdomen and wings.

The wings spring from the sides of the mesonotum and their venation is one of the important features of classification.

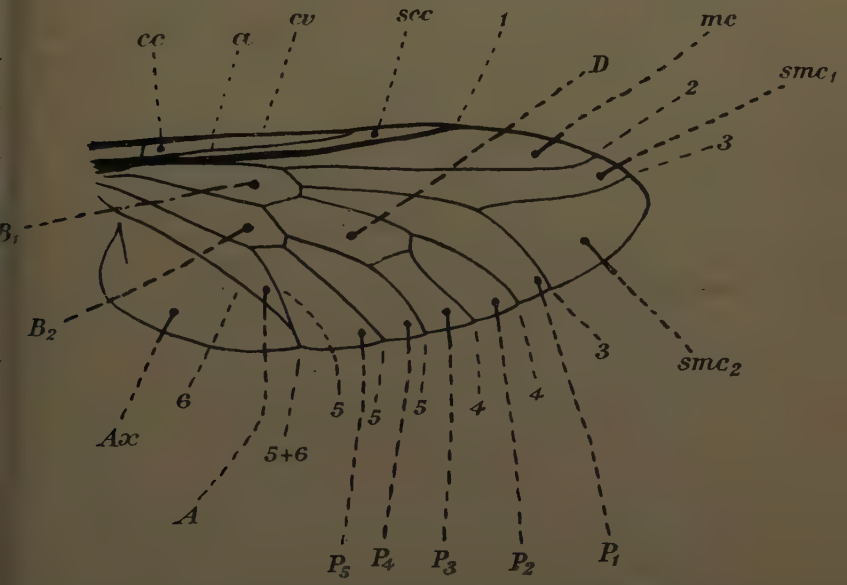


FIG. 142.—Wing of *Tabanus*, named after Williston.

cv = costal vein. 1–6 = 1st–6th longitudinal veins. *a* = auxiliary vein. B_1 = 1st basal cell. B_2 = 2nd basal cell. *D* = discal cell. P_1–P_5 = 1st–5th posterior cells. *cc* = costal cell. *scc* = sub-costal cell. *mc* = marginal cell. *smc* = sub-marginal cells. *A* = anal cell. *Ax* = axillary cell.

There are two systems of nomenclature of the venation of Dipterous wings, Comstock's and Williston's; exhaustive details of these two systems will be found in the authors' respective works, *Wings of Insects* and *North American Diptera*. We do not propose entering into a discussion on these systems, but in this connection see figs. 142 and 143. The posterior basal part of the wings is often cut into one, two, or three lobes, the "alula," "anti-squama," and "squama" respectively, the alula being the most distal of the three, and

the squama being proximal to the thorax. At rest, the antisquama lies over the squama and both cover the "halteres." These last are homologous with the hind-wings of other insects and are borne on the metanotum.

Each division of the thorax bears a pair of legs ventrally. Each leg is composed of a coxa, trochanter, femur, tibia, and five tarsi. The tibia may sometimes have a pre-apical bristle a little below the middle, and if it has one or more spines at the distal end it is said to be "spurred."

The tarsus consists of five joints, the proximal one being the metatarsus. The fifth joint usually bears a pair of claws

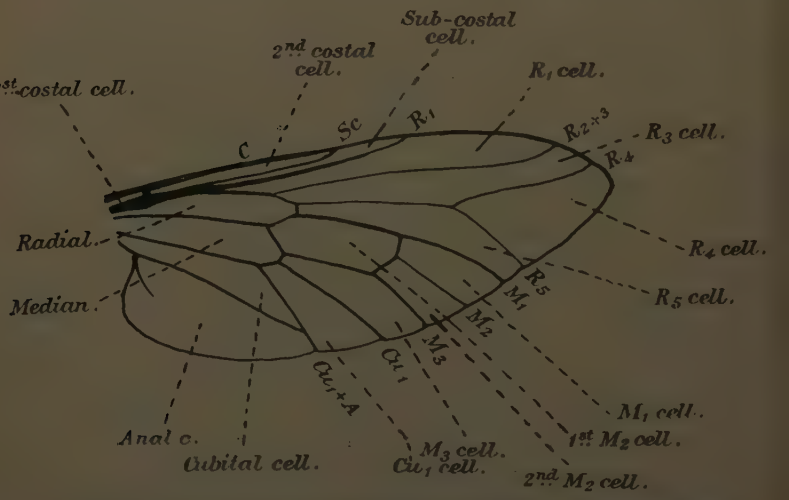


FIG. 143.—Wing of *Tabanus* (Comstock and Needham's nomenclature).

(ungues), under each of which is often a pad-like structure, the pulvillus. Between these may be a median structure, the empodium.

This is, as a rule, bristle-like, but is occasionally in the form of a pad, in which case it is said to be pulvilliform.

The abdomen consists of from nine segments (in some Tipulidæ) down to five (in some of the *Calyptratæ*), rarely four. The genitalia of the males are known collectively as the hypopygium. In some families they are very prominent, and are useful in classification. The ovipositor of the females is usually hidden, but in some cases projects; a few are very long.

The alimentary canal consists of the pharynx, œsophagus, and the characteristic "proventriculus" or sucking stomach. Behind is the true stomach, into the posterior end of which enter the Malpighian tubules, usually four, rarely five, in number, which sometimes unite into one or two ducts leading into the intestine.

In the nervous system there is a ventral chain of ganglia, three thoracic and six abdominal, as found in the more primitive forms. As one passes towards the *Calyptratæ* one finds a

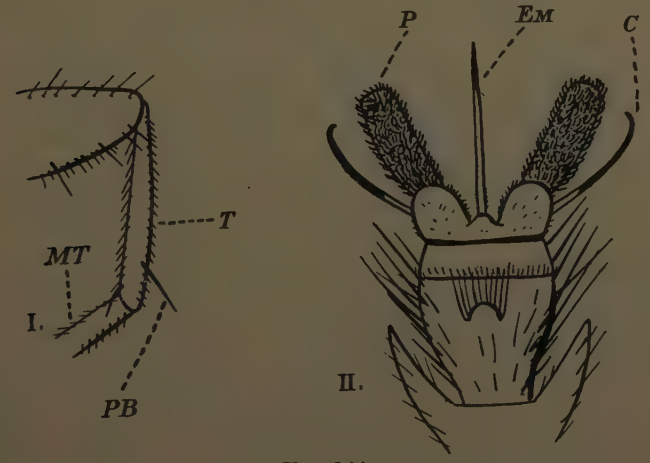


FIG. 144.

I. Part of Fore-leg of *Sapromyza prœusta*.

T = tibia. *PB* = pre-apical bristle. *MT* = metatarsus.

II. Last Tarsal Joint of *Conops* sp.

P = pulvillus. *EM* = empodium *C* = claw.

tendency for the ganglia to fuse up and in the later families but one ganglion is found.

The two tracheal trunks of the respiratory system expand at the base of the abdomen into bladder-like expansions.

The reproductive organs of the female consist of a large number of egg-tubes, three spermathecæ and a pair of accessory organs. The males possess a pair of testes, with short vasa deferentia and a well-developed penis and accessory organs.

The sense organs of flies are, with the exception of the halteres, located in the head. The eyes as a rule are well developed and adapted to appreciate movement. The predaceous flies catch their prey on the wing, and Kelly (1914) has given

an account of some species of *Sarcophaga* which endeavour to lay their young on grasshoppers as the latter pass through the air—though they are liable to larviposit indiscriminately on any small thing moving through the air, either other insects or balls of paper.

The sense of smell is located in the antennæ and palps and is better developed in *Diptera* than in the other orders. The sensory apparatus consists essentially of a hypodermal cell, a thin-walled chitinous process and a nerve fibre. These processes occur in different forms. In the *Nemocera* they occur singly or in small groups in all the joints of the antennæ and the palps, but in the *Brachycera* they are not found on the first two joints of the antennæ, and in the *Cyclorrhapha* they occur on the third joint alone. Groups of relatively few sensory processes are often situated in pits, especially in the *Cyclorrhapha*. The *Syrphidæ* show in addition a very large pit containing a great number of processes packed tightly together. Such a pit may occupy nearly the whole of the interior of the flagellum (K. M. Smith, 1919). The olfactory sense relationships of flies, to their food, to their breeding-places, and to each other, offers a wide field for research, and at present very little is known about them. Some flies are strongly attracted by specific substances, as Howlett (1912 and 1915) showed with regard to species of *Dacus*, the males being attracted to iso-eugenol, methyl-eugenol, or both, according to species. The males of the Mediterranean fruit-fly, *Ceratitis capitata*, are also attracted strongly by kerosene. Much work has been done on the chemotropic responses of the house-fly: O. Lodge (*Proc. Zoo. Soc. London*, 1916), etc. Imms and Husain (1920) give an account of the relationships between various chemical substances and their attractions for flies.

Metamorphosis in *Diptera* is complete. The larvæ are quite unlike the adult in every way. They are uniformly legless, though they may have processes on the segments to aid in locomotion.

The pupæ are obtect in most of the *Orthorrhapha*, coarctate in the remainder and in the *Cyclorrhapha*.

The larval and pupal period are relatively short, compared with other orders, a few days often being sufficient for development from egg to imago.

Flies must be fertilized before they can give rise to young. The exception to this is where pædogenesis occurs in *Cecidomyiidæ*: and Wasmann has stated that the termitophilous Phorid *Termitoxenia* is parthenogenetic. Eggs are commonly laid by flies, but there are many exceptions. The *Glossininæ* and larviparous *Pupipara* lay full-grown larvæ which pupate almost at once.

Flies are well represented all over the globe, but more especially in tropical regions where it is not too dry. In spite of their ubiquity they have to contend with numerous dangers.

I II

Fig. 145.—(I) Pupa of *Anopheles*. (× 15.) (After Patton and Cragg, with slight alterations.) (II) Puparium of *Musca domestica*. (× 6.)

Large numbers are parasitized in their larval stages by Chalcids, and also by members of a Dipterous family, the *Tachinidæ*. The adults fall a prey to the numerous forms of predaceous insects, to which may be added spiders and insectivorous vertebrates; the larvæ, aquatic as well as terrestrial, are the favourite food of many predators. On the other hand, they have become very adaptable, and cope better with the changes of natural conditions than the majority of the groups of insects.

The economic importance of flies rests mainly with the medical aspect. Of late years they have been shown to

convey in one way or another various diseases, and in some cases themselves are parasites in man or his stock. In a lesser degree they cause harm to cultivated vegetable products, members of the *Cecidomyiidæ* and *Trypetidæ* in particular doing widespread damage.

We are indebted to the late F. M. Howlett in his introduction to *Diptera* in *Indian Insect Life* for the sections on the Main Divisions of Diptera, the Life-histories in general, and the Past History and Development, which sections have here been quoted at length unaltered.

Classification.

The classification adopted is as follows :—

I. *Orthorrhapha*		
A. *Nemocera* . . .	13	families.
B. *Brachycera* . . .	16	,,
II. *Cyclorrhapha*		
A. *Aschiza* . . .	3	,,
B. *Schizophora* :		
(1) *Acalyptratæ* . .	19	,,
(2) *Calyptratæ* . .	6	,,
C. *Pupipara* . . .	4	,,

Note.—In describing the various families, use has been made of slightly vague terms when referring to size. *Musca domestica* has been taken as being a medium-sized fly, and the other expressions are relative to this. The minutest flies belong to the *Cecidomyiidæ*, the smallest being about one-fiftieth of an inch ; and all gradations are found up to the largest forms, about two inches long.

General Textbooks.—D. Sharp, Insects, vol. II, *Camb. Nat. Hist.* (1899). Williston, *North American Diptera* (1908). Howlett, Diptera, *Indian Insect Life* (1909). Patton and Cragg, *Textbook of Medical Entomology* (1913).

Sub-Order I. *ORTHORRHAPHA*

Flies which emerge through a longitudinal slit in the back of the thorax of the pupa.

(*a*) NEMOCERA

Antennæ with six or more joints ; palps rarely less than four- or five-jointed ; R_1, R_2, R_3 separate, R_4 and R_5 fused ; larvæ eucephalous with opposed mandibles.

Tipulidæ.

Crane-flies, Daddy-long-legs.

The mesonotum with a V-shaped suture. The costal vein runs round the wing. Discal cell present. Antennæ six to thirty-nine joints. Palpi four to five joints.

This family is widely distributed over the world. In size the flies are fairly small to large, slender and brownish in colour, with long, fragile legs. The sexes are easily distinguished by the shape of the abdomen, which in the female has a pointed ovipositor, and in the male is terminated by a pair of large, blunt clasping organs.

Crane-flies may be seen in the summer time flying about in a seemingly aimless manner over grassland, marshes and low-lying meadows and woodland. As soon as they issue from the pupa the flies are ready to mate, and a single female may lay upwards of 200 hard, seed-like eggs, pushing the ovipositor well into the ground for the purpose. The larvæ, commonly known as "leather-jackets," hatch in from seven to fifteen days (Rennie, 1917 and 1918). The integument is tough and leathery, and of a greyish or brownish colour. The number of segments is eleven to twelve, and the tracheal system metapneustic. The larvæ may be found in soil, decomposing woody matter, under bark and in water ; but a few species live above ground, eating the leafage of grasses and herbaceous plants. A small group, the *Cylindrotomini*, including six

Fig. 146.—Tipulid Larva. (× 1½)

species, are remarkable for the fact that the larvæ are green and live on the green parts of Bryophytes and flowering plants (Cameron, 1918). *Dictanomyia foliocunicutor* is a small form, little more than one-sixth of an inch long, whose larva mines the leaves of species of *Cyrtandra* in Hawaii. Pupation takes place in the mine (Swezey, 1915). One species breeds commonly under glass in England. Hibernation takes place in the larval stage, and pupation occurs in the spring. The pupæ develop transverse rows of bristles, which enable them to wriggle through the soil. There may be one or two broods a year. In the larval stage, Tipulids are of some economic importance, mainly in temperate regions, as they devour all kinds of roots, and attack indiscriminately grass and all sorts of cereals, turnips, mangolds, clover, peas, beans, cabbages and the decorative plants of gardens; in the aggregate pasture lands seem to suffer most, and especially the fine grasses of golf putting greens. The offenders belong chiefly to the genus *Tipula* (*T. oleracea*, *T. paludosa*, etc.)—also *Pachyrhina*.

Birds are important checks on the crane-fly, particularly starlings, rooks and ravens. Moles also have a great taste for them. Parasites belonging to the family *Tachinidæ* have been recorded from some species—*Admontia amica* (Bezzi and Stein), *Bucentes geniculata* from *T. oleracea* and *T. paludosa*, and *Siphona cristata* from *T. gigantea* (Rennie and Sutherland). Four species of *Empusa* have also been reported (F. Picard).

Control of leather-jackets depends much upon local circumstances; where it can be used, naphthalene at two or three hundredweight per acre is a good preventive. For gardens and golf greens naphthalene and powdered soap, watered in, is a specific cure.

Psychodidæ.

Moth-flies, Owl-midges, Sand-flies.

Wings with ten longitudinal veins; no cross-veins except at the base. Wings hairy and in a few forms with scales also.

These flies occur in all countries of the world. In size they are small to minute, with hairy wings, giving them a dull grey or brown moth-like appearance. The mouth-parts are

usually short, but in the genus *Phlebotomus* they are longer and rigid. The genitalia of the males are long and prominent, having a large pair of clasping organs, which is a ready means of identifying the sexes. The flies live in shady places and lay their eggs in decaying vegetation, dung, water, or in damp, stony situations. *Psychoda* is a common aquatic form, the larva living in algæ in still ponds; others live where water drips, feeding on the algæ.

Their economic importance is confined to the genus *Phlebotomus*, on account of its blood-sucking propensities. Flies of this genus are not found in the cooler climates, but are otherwise freely distributed throughout Southern Europe, the Mediterranean coast, North, East, and West Africa, Arabia, India and South America. They are known to be the vectors of Pappataci fever (also called three-day fever, sand-fly fever, etc.), in which three species are at present known to be concerned, *P. papatasii*, Scop.; *P. minutus*, Rond.; and *P. perniciosus*, Newst. Dengue may also be transmitted. *P. minutus* is also responsible for "Oriental sore" (Sergent and others, Paris, 1915). C. H. T. Townsend (Wash., 1915) claims *P. verrucarum* as the carrier of verruga in Peru. In the last two cases the flies are known to feed on lizards and other reptiles, which are regarded as the reservoir for the causal agents of those diseases.

The eggs of *Phlebotomus* are laid under damp stones, and in the cracks of masonry, walls, caves, etc., and hatch in six to nine days. The larvæ bear two pairs of long, caudal bristles and feed on the excreta of lizards, bats, woodlice and insects, and live about eight weeks. Pupation lasts about a fortnight. Both larvæ and adults shun the bright daylight and seek dark or shady habitats. They fly about during the dark hours if the air is still, but never far from their hiding-places, which they seek at once if any wind arises. Both sexes will suck up the juices of moist organic detritus, but the females alone suck blood.

Owing to the small size of these pests and the difficulty of locating their breeding-places, which may cover wide areas, control is a matter of considerable difficulty. Defensive measures against the adult seem to be the best that can be done at present.

Two parasites are at present known, one a species of *Herpetomonas* found by Mackie in India; and a fungus, *Empusa papatasii*, found by Marett in Malta.

R. Newstead, "The Pappataci Flies of the Maltese Islands," *Bull. of Ent. Res.* (1911).

Larrousse: *Étude Systématique et Médicale des Phlébotomes* (1921).

Dixidæ.

Proboscis projecting. Eyes round. Coxæ somewhat elongated. R_2 arises from R_1 near the middle of the wing; the radio-medial cross-vein close to the branching of R_2 and R_{4+5}.

These flies are smallish, having a general resemblance to mosquitos, from which, however, they differ in the wing venation, and in bearing no scales. The larvæ are aquatic, living at the edges of still or slowly running water, and are like those of the mosquitos. The adults frequent damp and sheltered places and have been seen dancing in swarms. The sexes may be distinguished by the termination of the abdomen, which in the females is pointed, in the males broad.

This is a very small family, having a single genus *Dixa*, containing rather more than twenty species.

They are of no known economic importance.

Culicidæ.

Mosquitos, Gnats.

Scales at least on the posterior margin of the wings, usually on the wings and body as well. Well-developed proboscis and palps. Antennæ long, in the male plumose. Eyes reniform.

Mosquitos are to be found in all parts of the world. They are active in damp, warm weather, but chiefly during the dark hours and in the shade of woods and forests. Either cold or dryness adversely affects their activity. Their food consists of plant-juices, for which their mouth-parts are prominent

and rigid, and formed for sucking. A large number of species habitually suck blood for food, a custom confined to the females, which may be thereby identified as such. The plumosity of the male antennæ is a further sex distinction.

Their eggs are laid on or near the surface of water, either singly (*Anopheles*, *Stegomyia*, *Aëdes*) or in raft-like masses (*Culex*). The number laid may vary from about 40 (*A. maculipennis*) to 400 or so (*C. pipiens*). The eggs of *Anopheles*, etc., are provided with air chambers, enabling them to float on the surface. The larvæ of all forms in this family are, so far as is known, aquatic. They have a distinct head with well-developed jaws, some being vegetable feeders and others predaceous even to cannibalism. The larvæ breathe through a pair of orifices on the dorsum of the eighth abdominal segment which are surrounded by a fringe of hairs in the sub-family *Anophelinæ*, while in the *Culicinæ* there is a projecting tube in addition, which structure serves to identify the sub-family to which the larva belongs. A further distinction is found in the breathing position on the surface: the Anophelines hang parallel to the surface, attached by tufts of hairs along their backs, but the Culicines hang at an angle, suspended only by the circlet of hairs at the apex of the respiratory tube. Breathing may also take place through tracheal gills round the anus, but this is insufficient to maintain life by itself. The larvæ of the genus *Mansonia* have the curious habit of boring their siphons into the stems of water plants, from which they obtain their oxygen (Wesemberg-Lund, 1918).

Fig. 147.—Larva of *Culex* sp. (× 6.)

The larva moults four times during its life, which is very variable in length. The pupa is also aquatic and is capable

of active movements. In the pupa, abdominal respiration is replaced by a pair of trumpets, attached to the thoracic segment. In appearance the pupa is comma-shaped, and is suspended from the surface by hairs on the first abdominal segment. The length of the pupal stage is two or three days, which may be prolonged by cold temperature. When the adult is about to come out, the pupa straightens out along the surface of the water, and the imago emerges through a crack along the dorsal surface of the pupal skin.

In colder climates, hibernation takes place in both larval and adult stages. In tropical countries, adults remain quiescent during the dry season (æstivation).

The *Culicidæ* form an extremely important economic group. Since 1878, when Manson discovered that the transmission of Filariasis was due to mosquitos, they have been shown also to convey malaria, yellow fever and dengue ; K. Deszimirovics (1917) also reports that epidemic jaundice is spread by them. Hence the bionomics of Mosquitos and control measures against them, have been subjects of a vast amount of research and literature. The general measures adopted against these pests may be summarized as under :—

A. Destruction of larvæ.

(1) By draining marshy land.

(2) By covering the surface of the water with some substance which prevents respiration, such as cork-dust, duckweed, or some sort of oil. The first has been used in wells with success, the second in ponds. Oiling is probably the most important of these for large sheets of water and temporary pools. It has been shown that paraffin oil containing 1 per cent. of castor oil spreads over a very much larger area (25 times) than paraffin alone and moreover the film does not break so readily (W. N. Leak, 1921).

According to Caballero (1922), species of the alga *Chara* excrete a substance which is fatal to mosquito larvæ. After examining a large number of likely breeding-places, this author found no larvæ whatever in places (upwards of 300) where *Chara* species were present, but abundance of them where this alga was absent. This is not confirmed.

(3) Natural enemies. Many predaceous aquatic animals are known to attack the larvæ. These include fish, the larvæ of

dragon-flies, water-beetles and water-bugs, tadpoles, frogs, and newts. Some of the carnivorous mosquito larvæ also attack their relations.

Of these, small fish of many species seem to promise most. They have been introduced with success into Madagascar and Zanzibar, and are used with great effect in the drinking-wells of Gambia (Kennedy, 1913). Where fish are employed the water should be kept free from weeds.

B. Defensive measures against the adult. These include:

(1) The destruction near habitations of bushes, scrub, etc., which are used by the flies for shelter.

(2) The screening of dwellings.

Various animals attack mosquitos, including birds of various kinds, bats, spiders, dragon-flies, some species of *Ceratopogon*, and so on. Trematodes and fungi have been found parasitizing the larvæ.

Quinine prophylaxis is very important in the control of such diseases as malaria, and should be practised by all sojourning in malarial regions, as this tends to diminish the reservoirs of the malarial parasite.

G. Giles (1902); Theobald, *Monograph of the Culicidæ of the World* (1901–1910), and *Gen. Ins.*, Fasc. 26 (1905); Patton and Cragg, *Medical Entomology* (1913); E. Hindle (1914); Prince and Orenstein, *Mosquito Control in Panama* (1915).

Chironomidæ.

Midges.

Proboscis short; male antennæ plumose; the costal vein extending only to the tip of the wing.

These small flies are often seen in swarms on still evenings. Many of them are blood-sucking and have an irritating "bite." They may be distinguished from mosquitos by their smaller size, the fact that the costa reaches only the tip of the wing, by the absence of scales, and by their habit of resting with their fore-legs raised.

Their eggs are laid in decaying vegetable matter, behind bark, in water. The *Ceratopogoninæ* lay them in small clusters

on aquatic objects, while the *Tanypinæ* and *Chironominæ* lay them embedded in long strips of jelly.

Most of the larvæ are aquatic, have their tracheal system closed and in some cases rudimentary. There are blood gills on the apical abdominal segments of *Chironomus*. Some species of this genus are red ("blood-worms"), the colour being due to hæmoglobin, and such forms have been found at a depth of 1,000 feet in Lake Superior. They have a bunch of hooks under the head and a paired, hook like process at the apex of the abdomen. There are other forms which contain a green pigment. Some live in the stems of water plants, and others make tubes or cases of material like silk. They are amongst the commonest of aquatic insects.

Fig. 148.—Larva of *Chironomus*. (× 6.)

The small green larvæ of *Orthocladius vernalis* have lately been seen attacking the roots of saxifrage in large numbers. Seedlings of *Campanula colorata* were also attacked by them, in this case above ground, both stems and cotyledons being bitten. The full-grown larvæ are olive green, and 5 mm. long by 0·4 mm. broad. The pupal stage was two to three days at the beginning of April (1922), and all imagines were female (Fox-Wilson).

The pupæ as well as the larvæ are active and breathe through tracheal gills. Grimm (1871) has described a very interesting form of parthenogenesis in the spring generation of one species, in which the pupa deposits eggs a short time before becoming an imago.

Up to now the midges have not been proved to convey disease, but at present they are suspect in at least three cases, viz.:

(1) Leishmaniasis in the Amazon basin (E. L. Walker, N. Orleans, 1917); (2) horse-sickness in the Belgian Congo (van Saceghem, Paris, 1918); and (3) a fever especially prevalent amongst children in Korea (S. Kinoshita, Tokyo, 1918).

J. J. Kieffer, *Gen. Ins.*, Fasc. 42 (1906).

Cecidomyiidæ.

Gall-gnats.

Antennæ long; legs long and slender; tibiæ without spurs; coxæ short; wings hairy, few longitudinal veins, no cross-veins.

These form an extensive family of minute and delicate flies and are widely distributed. The antennæ are provided with whorls of hair, which are often more bushy in the males.

The larvæ are remarkable in having fourteen segments and for the possession, in many species, of a sternal spatula or "breast-bone" projecting from the first thoracic segment. A further fact of great interest is the occurrence of pædogenesis in two genera, *Miastor* and *Oligarces*. A larva, instead of maturing normally and pupating, produces a number of young maggots, and this form of reproduction may be carried on through successive generations during autumn, winter, and spring (Meinert, 1874). The larvæ are plant-feeders, some forms alternating between two different plants, e.g. *C. sisymbii* on barberry and nasturtium. Although a few live on the stems of plants, like *Mayetiola destructor*, the Hessian fly, the majority get inside, and produce galls, while some species live as inquilines in such galls. One recently discovered form makes a gall on *Hypochnus*, a bark-encrusting fungus (Edwards, *Ent. Mo. Mag.*, 1922).

Fig. 149.—Larva of *Dasyneura rhodophaga*. (× 25.)
(After Sasscer and Borden.)

A few live on the dejecta of the larvæ of other insects, and of cattle and birds.

The family shows a wide variety of habit and so we find that they feed on animals in different ways. They may prey on Aphids, Psyllids, Coccids, mites, and probably also small beetles. As an enemy of Aphids, J. J. Davis (1916) considers the larvæ of *Aphidoletes meridionalis* to be extremely important. A few are known as parasites, such as *Endaphis perfidus* in *Aphis platanoides*, and *Endopsylla agilis* in *Tingis pyri*.

Economically, the family presents a few important forms.

Mayetiola destructor, the Hessian fly, attacks cereals and grasses. The fly lays eggs in the grooves of the upper surface of the leaf of wheat, barley or rye. They are about 2 mm. long, cigar-shaped and pinkish. Within a week or so they hatch and the larvæ descend within the sheathing base of the leaf, where they remain till full grown. They then pupate, exuding some substance which turns brown and hardens, giving them the appearance of flax-seeds, and in this state they pass the winter. In England there is one brood—in America, two.

Contarinia pyrivora is a destructive pest on pears in Europe and North America. It lays eggs in the flowers, and the larvæ bore into the young fruit, which does not develop properly and drops off. The larvæ pupate in the soil and so remain until the following spring, when the adults emerge. The remedies suggested are to burn all damaged fruit, and to cultivate the ground round the trees, about July, with caustic lime. One parasite is recorded, *Inostemma pyricola*.

Perrisia pyri is another form which attacks pear trees in the northern hemisphere. Known as the "leaf-curling midge," it appears in the spring about May, a small, dark brown fly, about $\frac{1}{12}$ inch long. It lays its eggs on the young leaves, which later roll up on one or both sides lengthwise. Small white maggots may be seen when the rolls are unfurled. When mature, the larvæ leave their shelter and pupate in the ground.

The midges from these pupæ emerge about August, there being two broods in the year in this country.

The best remedy appears to be to spread some soil insecticide

on the soil beneath the trees about midsummer, to kill the larvæ.

Contarinia tritici, the wheat-midge, is also troublesome at times. Good cultivation seems to be the best one can do against cereal pests such as these.

Several species of Chalcids are known to parasitize these flies.

Miall and Hammond, *The Harlequin Fly* (1900); J. J. Kieffer, Monograph of the *Cecidomyiidæ* (1900); J. J. Kieffer, *Genera Insectorum*, 152 (1913).

Also of economic inportance are: *Cecidomyia*, *Diplosis*, *Dasyneura*, *Lasioptera*, and *Oligotrophes*.

Mycetophilidæ.

Fungus-gnats.

Coxæ elongate; antennæ long; tibiæ spurred; no cross-vein between median and discal cells.

This family contains a large number of species and is freely distributed over the globe. The flies are small, delicate, and slender, are found in damp, shady situations and may be quickly identified by the elongate coxæ. The males may be distinguished by the rather prominent clasping organs, while the extremity of the abdomen in the female is pointed.

Eggs are laid in fungi, decaying wood, and other vegetable material in damp situations. The larvæ are white and rather transparent, and are peripneustic. Many larvæ spin webs, or secrete mucus, and some species of *Sciara* form themselves into immense ribbons by means of this mucus, the whole apparently being a migrating procession, though for what purpose is not known. The larvæ present many other peculiarities. A species of *Mycetophila* makes over itself a roof of excrement, laid on spirally, so that it has somewhat the appearance of a mollusc. In New Zealand *Bolitophila* is luminous, as is also a species of *Ceroplatus* in Australia.

Many genera and species occur in amber.

The fungus-gnats are of some economic importance, in so far as they attack artificially reared mushrooms.

Sciara præcox is a pest on mushrooms in this country. C. B. Symes (1921) gives an account of it, of which the following is an abstract :—

The eggs are laid sometimes singly, sometimes in batches or strings of nine to twelve, at the base or the top of the pileus, or between the gills. The total number of eggs laid by a female is thirty to thirty-five. In favourable temperatures they hatch in five to six days. The larval period depends much on the temperature, but may be seventeen to twenty-four days, during which there are three moults. They pupate either in the mushroom or in the soil near the surface. The pupal period is from five to eleven days and the adults start pairing twenty-four hours after emergence. The whole cycle lasts from four to six weeks, and there are four broods in the year.

The adults may be seen running about over the mushroom beds, rarely flying. They do considerable damage, chiefly in the third and fourth generations. The damage is often followed by attacks of *Tyroglyphidæ*, of a springtail, *Achorutes armatus*, and of a parasitic fungus of the genus *Hypomyces* and of bacteria.

C. A. Johannson, *Gen. Ins.*, Fasc. 93 (1909).

Bibionidæ.

Antennæ of nine to twelve short, thick joints ; eyes of male holoptic, or nearly so ; no discal cell, but median cell usually complete ; coxæ short ; front femora thick and front tibiæ spinose.

Small to moderately large flies, the flight of which is not very strong. The eyes of the males are divided transversely, the facets of the lower portions being larger than those of the upper ones.

The family is a widely distributed one. The larvæ are found commonly in decaying vegetable matter, and in the soil. They are usually dark-coloured, leathery and with a well-developed head.

H. B. Morris (1917) gives some account of *Bibio johannis*, the larvæ of which are found in pasture land, among the roots

of grasses. They feed on soil and organic matter. The eggs, under laboratory conditions, took forty-eight days to hatch. The first instar has long setæ on each segment, and a single pair of spiracles on the last segment, there being twelve segments altogether, plus the head. After nineteen days, it moulted. The second instar has blunt processes on each segment in place of the bristles, and there are two more pairs of spiracles, on the first and tenth segments respectively. The last instar has a well-developed head and mandibles and ten pairs of spiracles. It pupates in a cell in the soil. The pupa is from 7 to 8 mm. long and bears on the last segment a pair of stout processes and also a pair of spiracles on all segments except the eighth. It is recorded as attacking larch seedlings and hop roots.

Fig. 150.—Bibionid Larva. (× 6.)

Several species are mentioned as being of economic importance, damaging the roots of oats, grass, lettuces, seedling cabbages, young flower plants, tomatoes, ash seedlings, sugar beet, spring barley and celery.

Sudeikin (1913) records *Bibio hortulanus* as attacking the roots of wheat very severely.

Simuliidæ.

Buffalo-gnats.

Antennæ short, ten to eleven joints ; no ocelli ; eyes in the male holoptic ; anterior veins well marked, posterior ones weak.

The flies of this family are grouped in one genus, *Simulium*, and are to be found all over the world. They are small and like the *Bibionidæ*, have both large and small facets to their eyes. The females are blood-sucking and are recognizable by the space between the eyes.

The eggs, laid under water, are attached to stones and

plants of quick-running streams. In from three to twelve days they hatch and the larvæ attach themselves to stones by means of an anal sucker and breathe through three anal gills. They spin threads across the stream and move along these. They feed on minute organisms which are wafted into the mouth by a pair of brush-like appendages situated close to the antennæ. The larvæ live about two or three weeks and then proceed to spin a cocoon, assisted by a spiny proleg on the venter of the first thoracic segment. The cocoon is tied by threads to various objects and, once firmly established, the naked and free pupa lies in the open end and breathes the air in the water through two bunches of long, slender filaments. The imago escapes under water and rises to the surface in a bubble of air. Being blood-sucking creatures, the female gnats must be suspect of conveying disease until proved otherwise. At present they are suspected in South America of conveying Leishmaniasis. However this may be, they are sometimes an intolerable nuisance to cattle when they bite in large numbers. In America cattle have been driven mad by their persecution, and deaths among the herds are not uncommon.—Coal-tar and fish oils have been used as repellents with some success. They have also been reported as a nuisance to poultry near Cape Town (C. Fuller, 1913).

J. Wilhelm, *Die Kriegelmücken*, Jena (1920).

Blepharoceridæ.

Wings with creases, having the appearance of a secondary venation. No discal cell. Thorax with incomplete suture.

Small, gnat-like flies, having a long pair of hind-legs, and like the two previous families, having the facets of the eyes differentiated in upper and lower portions. The wings are broad and have a netted and iridescent appearance. The mouth-parts are elongate and the females have long saw-like mandibles. The extremity of the abdomen is broad in the males and pointed in the females.

Eggs are laid on wet stones by shallow, fast-running streams. The larva lies flat in the water, attached to a stone by six

ventral suckers. The food is mostly diatoms. The pupæ are attached in a similar manner; when emerging, the fly makes its way out through a crack in the dorsum of the pupal skin and rises to the surface, clinging with its long hind-legs to the skin of the pupa. Then, the body of the fly being above the surface of the water, it expands its wings and flies away.

This is a remarkable and very specialized way of emerging and if the water be a little too deep, the imago is doomed to death. In the circumstances, it is restricted to very local habitats, but is found sparingly in S. Europe, N. America, W. Indies, Mexico, Brazil, Ceylon, India, Japan, Australia, and New Zealand.

The adult females are predaceous, mostly on *Chironomidæ*. The males are flower-feeders.

Kellogg, *Gen. Ins.*, Fasc. 56 (1907).

Deuterophlebiidæ.

The above is a family erected by F. W. Edwards (1922) upon two males of the same species, *Deuterophlebia mirabilis*. The following are the characters given of this remarkable insect (*Ann. and Mag. of N.H.*, April, 1922):

Head hidden beneath projecting mesonotum; antennæ six-segmented, the first five joints relatively small, the sixth joint several times longer than the body; mouth-parts absent; no ocelli; tarsi with large empodia and a single claw; tibial spurs absent; wings large, covered densely with fine hairs; true veins almost absent, but an elaborate fan-like development of secondary folds present.

The insects from which the above description was made were found floating on the edge of Lake Gungabal, near Srinagar, Kashmir, 11,700 feet above sea-level.

Their colour is a dull black and they have a well-developed hypopygium. In the general shape of the body and wings they resemble the *Blepharoceridæ*; the secondary "venation" is also common to both, though in *D. mirabilis* it is on a plan entirely different from the Blepharocerids.

Orphnephilidæ.

Antennæ short, consisting of two joints and an arista, the second joint and arista being composed of ten to eleven segments, the last terminating in a bristle. No ocelli and no discal cell.

These are rare flies, but have a wide distribution. They are small and bare and are found on the banks of streams. Little is known of their life-history, and they appear to have no economic significance.

Rhyphidæ.

Discal cell present; empodia pulvilliform; pulvilli rudimentary or absent. No transverse suture on thorax.

The *Rhyphidæ* have a wide distribution and have the general appearance of small crane-flies. They are fond of shady places.

The larvæ are amphipneustic and are found in rotten fruit, manure and decayed wood, but they are mostly aquatic.

(*b*) BRACHYCERA

Antennæ variable, from many-jointed to two or three simple joints; palps two- or one-jointed; discal cell nearly always present; R_1, R_4, R_5 separate, R_2 and R_3 fused; larvæ with vertically moving mandibles and with retractile head (except in Stratiomyidæ and some Leptidæ).

Leptidæ.

Empodia pulvilliform; pulvilli present; at least posterior tibiæ with spurs.

Flies of moderate size, with wide heads and large eyes. The space between the eyes is greater in the females than the males.

Eggs are laid in damp and shady localities. *Atherix* females mass together and lay their eggs in a solid lump on plants overhanging water, and there die. The larvæ are predaceous, living in wood under bark or in the earth. Some species of

the genera *Vermileo* and *Lampromyia* make a pit in dry sand and catch their prey like an ant-lion. The pupæ are free.

A few forms are known to suck blood occasionally, but it is not common, and they do not appear to have any economic importance.

Stratiomyidæ.

Third joint of antennæ annulated. Palpi two-jointed. Tibiæ without spurs. Costal vein never further than tip of wing ; discal cell present ; empodia pulvilliform.

This is a large family with a wide distribution. The flies are fairly small to fairly large, either bare or thinly pilose, never with bristles. The wings are long and narrow, the discal cell being at once an obvious feature in the venation. The eyes of the male are closer together than are those of the females.

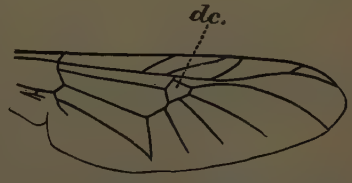


Fig. 151.—Wing of *Sargus flavipes*. *dc.* = discal cell.

Eggs are laid in or near water, in the ground, or in vegetable refuse. The larvæ are carnivorous or herbivorous. The pupæ are enclosed in the larval skin and are inactive. The beautiful larva of *Stratiomys chameleon* has been well described by the great naturalists Swammerdam and Réaumur, and figured by the former.

They are of no economic importance.

Verrall (1909) has monographed the British species.

Tabanidæ.

Gad-flies, horse-flies, breeze-flies, clegs.

Antennæ three-jointed, the last joint pointed and composed of four to eight annuli ; eyes large and broad, holoptic in the male ; squamæ well developed ; empodia pulvilliform ; R_4 and R_5 separate.

This is an extensive family of about 3,000 known species, and widely distributed in all countries. They are mostly large

flies, having a large head due chiefly to the development of the eyes, which are often brightly coloured with green, purple or brown. These colours fade after the death of the insect, leaving a mottled grey or brown appearance. The antennæ often point forwards and outwards and sometimes have a blunt spur at the base of the third joint. There are no bristles, but the thorax and abdomen may be covered with hairs. The proboscis is rigid and when short points downwards, when long points forwards. In the genus *Pangonia* the proboscis may be considerably longer than the body. The sexes may be distinguished by the space between the eyes at the vertex. In many forms there are also secondary differences in colour.

The eggs are cigar-shaped and dark, and are laid in regular masses on the leaves of plants close to water. The larvæ hatch in about a week and live either in the water, or in the mud and under stones in damp situations ; they are very voracious and feed on dead and living insects, on worms, etc., and often

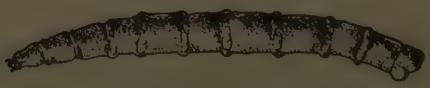


Fig. 152.—Larva of *Tabanus virgo*.
(After Patton and Cragg).

on one another. They are cylindrical, but pointed at both ends, and have eleven segments. Their respiratory arrangement is metapneustic, and they breathe through a siphon situated above the anus. There is a median structure within, known as Graber's organ, lying posteriorly between the tracheæ, the function of which is unknown.

The females are blood-suckers, and have recently been proved (in the case of two species of *Chrysops*) to transmit the filaria Loa loa to healthy animals (Connal and Connal, 1921). The worms gain exit by the labella of the fly and burrow through the skin of the vertebrate host. It was previously reported by Kleine that 5 per cent. of Chrysops flies examined at Eseka, in the Kameruns, in 1915, were infected with filaria and that the local population was heavily infected with it.

Evidence is also accumulating to show that Tabanids may cause the mechanical spread of Surra (Cross, 1923) and certain equine trypanosome diseases in India, Africa, and the Philip-

pines (Mitzmain in the *Philippine Jour. of Sci.*, sec. B, June, 1913). The geographical and seasonal distribution of some Tabanids agrees closely with the outbreaks of Surra.

Their natural enemies are *Asilidæ* and *Bembex*.

Surcouf lists the family, *Gen. Ins.* 175 (1921).

Acanthomeridæ.

Third joint of antennæ complex; palpi two-jointed. Tibiæ without spurs; empodia pulvilliform. Eyes holoptic in the male.

Mostly bare flies, large and stout. They are found in South and Tropical America, living in forests.

Little at present is known about them.

Cyrtidæ.

Antennæ of two or three joints, with or without terminal arista. Squamæ very large and inflated; empodia pulvilliform.

These flies have a small head, but large eyes, and the thorax is large and spherical. The large squama is a strong character for this group. The proboscis of some forms is very long.

The larvæ are parasitic on spiders.

Nemestrinidæ.

Antennæ with three joints and a terminal jointed arista; tibiæ without spurs; empodia pulvilliform.

These forms have a rather scattered distribution, occurring in Australia and South America and in places where the climate is dry and hot. The venation is curious, the veins running more or less parallel with the hind margin of the wing; in extreme cases there is a network on the distal half of the wing. The proboscis is elongate and is exaggerated in a few species, notably *Megistorhyncus longirostris*, from Africa, in which it reaches a length of about three inches.

Not much is known of the life-history of these flies. The eggs of one species appear to be laid in trees; on hatching, the larvæ spin a little silk and are carried away by the wind. In some way they come in contact with a beetle and are carried to its burrow. Subsequently, the larvæ feed on the grubs of the beetle.

Apioceridæ.

Antennæ three-jointed, with a short, stout, terminal style; palpi one- or two-jointed, the ends large and spatulate. Empodia absent; R_4 and R_5 separate; M_{1+2} terminating before the tip of the wing.

This family is a small one, with few species, found mostly in America and Australia. The adults are flower-loving; but nothing much is known about them.

Mydaidæ.

Antennæ four-jointed, the fourth joint elongate; empodia present, but not pulvilliform. Proboscis fleshy; R_4 and R_5 separate; M_1 turned up and terminating before the tip of the wing.

All large flies, mainly from North and South America and Australia.

The larvæ live in decaying wood, and some are predaceous on the grubs of wood-beetles. The adults are predaceous.

Asilidæ.

Robber-flies, Assassin-flies.

Antennæ three-jointed; proboscis horny and rigid. Empodia setiform or wanting.

This is a large family of large flies, sometimes bare, but usually with well-developed bristles. They constitute one of the dominant families of *Diptera*, and are found all over the world. They are powerful flies, extremely predaceous, and

attack all kinds of insects on the wing. The sexes may be easily distinguished by the prominent hypopygium in the male and the pointed ovipositor in the female. They are very variable in shape, from thin and narrow, after the manner of Tipulids (e.g. *Leptogaster*), to large robust flies, strongly coloured, like many of the larger *Hymenoptera*, to some of which, indeed, a few bear a very strong resemblance (e.g. *Laphria*, *Dasyllis*, *Rhopalogastor*, *Mallophora* and *Promachus bomboides*). The wings are white or smoky.

The larvæ live in rotting wood, leaves, etc., and under bark, and are also predaceous. The pupæ are free.

They have no economic importance, except in so far as they help to keep down the inimical insect population.

Therevidæ.

Antennæ of three joints and terminal style; proboscis fleshy; palpi two-jointed. Eyes of male holoptic or nearly so. Genitalia not prominent; empodia absent.

Large flies, in general resembling the *Asilidæ* in form and habits, but the soft proboscis and less strongly developed legs serve to distinguish them. The sexes may be determined by the eyes.

The larvæ differ considerably in appearance from those of *Asilidæ*, being long and slender and of apparently nineteen segments. They are amphipneustic, and live in earth, sand or rotting wood. The pupæ are free.

O. Kröber, *Gen. Ins.*, Fasc. 148 (1913).

Scenopinidæ.

Window-flies.

Antennæ three-jointed, without style or arista. Empodia absent. Males usually holoptic.

Rather small flies, usually black and bare, often to be found on windows.

The larvæ are long and slender, showing apparently nineteen segments, as in the *Therevidæ*. They live in decaying fungi

and wood, and also under carpets and furniture; the latter are said to live on the larvæ of flies and clothes moths.

O. Kröber, *Gen. Ins.*, Fasc. 161 (1914).

Bombyliidæ.

Antennæ three-jointed, with small style. Eyes of male usually holoptic, rarely so in the female.

Small to rather large flies, often covered with thick hair, and the wings with dark markings. The flies are sun-loving and are flower-feeders.

The larvæ are amphipneustic, and many forms are parasitic on other insects. Those parasitic on the mason-bees have a remarkable life-history, which has been elucidated by Fabre; hypermetamorphosis is a feature of this.

Empidæ.

Antennæ two- or three-jointed, with or without style or arista. Proboscis short or long, and rigid.

These flies may be anything from minute to large, of more slender build than the *Bombyliidæ*. The most recognizable feature is the spike-like proboscis. They are predaceous on other flies.

The habits in courtship of many species are definite and elaborate, reminding one of those of birds. Howlett (*Ent. Mag.*, 1907) has given an interesting account of *Empis borealis*. It is the custom in this species for the females to dance in the air in swarms when ready for pairing. A male fly, having caught some insect—usually a fly of some kind—flies near the swarm, holding its prey unharmed. A female is selected and chased—a short struggle ensues, during which the prey is transferred to the female—and both come to rest on some plant, copulation having now begun. During this period, the male hangs on to his support with the front legs, holding the female and her meal with his posterior pairs; and the female sucks the insect's juices. Should coitus be over before the meal is finished, the insect is at once discarded. The males were never

seen to feed; neither were the females except during copulation —and Howlett considers that the meal at such a time is a physiological necessity. Hamm (1908, ibid.) confirmed these results, and noted that they were much the same in some other species. He noted in the case of other forms (1909, ibid.) that pairing might take place by the male flying about over the ground of a meadow with prey, inducing a female to rise and join him. In another genus, pairing may take place on a leaf, after a considerable overture of matrimonial blandishment on either side.

Dolichopodidæ.

Median and discal cells confluent. Arista dorsal or terminal on a three-jointed antenna. Hypopygium conspicuous.

The members of this family are usually green, rarely yellow or black. The males exhibit a great variety of secondary sexual characters. All are predaceous on smaller flies.

The larvæ are found in earth which is rich in humus. The pupæ are usually free and breathe mainly through a pair of thoracic horns.

Phoridæ.

Antennæ three-jointed, the third joint more or less globose and concealing the other two. The wings usually large, with two strongly marked anterior veins and three or four other weaker, unbranched ones.

The family comprises small and minute flies, usually recognizable by the antennæ and the venation. A few are wingless. Some have peculiar habits and a few are myrmecophilous. Two genera live with Termites and have become so modified that they are hardly recognizable as flies. *Termitoxenia* is remarkable in that it gives birth to adults. The adults live on dead animal matter. The abdomen of the female is more pointed than that of the male.

The larvæ may be found in decaying vegetable matter, but some parasitize ants and the eggs of spiders.

The pupa is oval and segmented, and has a pair of respiratory tubes on the metathorax.

C. T. Brues, *Gen. Ins.*, Fasc. 44 (1906).

Lonchopteridæ.

Antennæ three-jointed, with terminal style. Wings pointed.

Small brownish flies, recognizable by the pointed wings. The larvæ are flat and live in vegetable matter.

Sub-Order II. *CYCLORRHAPHA*

A frontal lunule above the base of the antennæ ; third joint of antenna simple ; palpi unjointed ; pupa enclosed in last larval skin ; imago emerging by pushing off the end of the puparium.

(*a*) ASCHIZA

No frontal suture ; larvæ with two to four pairs of chitinized processes, working horizontally in addition to the pair of mouth-hooks.

Platypezidæ.

Arista terminal ; the males have the hind tarsi enlarged, and the eyes holoptic ; first posterior cell wide open.

This family is unimportant economically. The males are distinguished from the females by the appearance of the eyes and the hind tarsi.

The larvæ are broad and flat and fringed with spines. They live between the gills of fungi.

Pipunculidæ.

Arista dorsal ; head spherical and larger than the thorax.

The size of the head in these flies is due to the great development of the eyes, which take up almost all the surface of the head. The hypopygium of the male is prominent.

The larvæ are parasitic on *Rhynchota*, while the adults are flower-feeders. The flies are strong and accurate fliers.

Several species of *Pipunculus* have been recorded from Hawaii and California on the sugar-cane leaf hoppers *Eutettix tenella* and *Perkinsiella saccharicida* respectively. According to Williams (1918) one form which preys on the hoppers picks up an immature bug, oviposits in it in the air and then drops it.

Syrphidæ.

Hover-flies.

A spurious vein runs between R_5 and M_1.

The above single character is peculiar to Syrphids, by which they may easily be recognized. They are brightly coloured flies, usually striped with black and yellow, many resembling wasps, some duller coloured and furry, resembling bees. Their

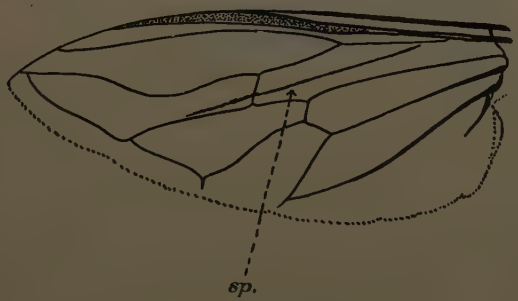


Fig. 153.—Wing of *Syrphid*.
sp. = spurious vein.

habit of hovering in the air has given the name of hover-flies.

The family is one of the largest of the *Diptera*, and is well represented in all parts of the world.

Eggs are laid in decaying vegetable matter, on the stems of plants, on fungi and on leaves (e.g. *Syrphus* spp.).

The larvæ are pointed at the anterior end and there are no external mouth-parts. The body presents a creamy, wrinkled appearance. Some species have an extensible breathing-tube at the posterior end, giving the whole a characteristic appear-

ance and earning for them the name of " rat-tailed " maggots. These include the genus *Eristalis*, which lives in putrescent filth, the adults of which resemble honey-bees. This no doubt gave rise to the legend that bees could be reared from rotting carcases. The larvæ of *Volucella* inhabit the nests of bees and wasps, acting as scavengers ; and those of *Microdon* are found in ants' nests. These last have a very curious appearance, and look less like maggots than molluscs. Some species of *Merodon* attack bulbs of the Narcissus family and constitute a pest to the gardener.

Economically, many forms are an important check on Aphids. The females search for Aphids, and lay eggs singly amongst them : under laboratory conditions not more than ten eggs are so laid per female ; but the larva is capable of eating 800–900 aphids during its development. Hibernation of these forms usually takes place as puparia, but sometimes in the adult or larval state (Staniland, 1922).

Verrall, *British Flies—Syrphidæ* (1901).

(*b*) SCHIZOPHORA

A frontal suture as well as a frontal lunule ; larvæ with head very reduced, and a pair of mouth-hooks only.

(i) *Acalyptratæ.*

Squamæ small or vestigial ; males never holoptic ; transverse suture incomplete ; first posterior cell widely open.

Conopidæ.

Antennæ porrect, with dorsal arista or terminal style ; proboscis long ; genitalia conspicuous ; abdomen often constricted forward ; first posterior cell closed or narrowed.

More or less elongate flies, bare or nearly so, but sometimes with a short golden pubescence, and often coloured with yellow, red, or black, some resembling wasps. The head is large and the eyes are broadly separated.

Most, if not all, parasitize bees, wasps, and *Orthoptera ;*

apparently the eggs are laid on the bodies of *Hymenoptera* while in flight (Williston). On hatching, the larva burrows into its host and develops at its expense until fully grown. The adult fly emerges between the abdominal segments of the host. The adults are flower-flies.

Micropezidæ.

Head subspherical; face retreating in profile; oral vibrissæ absent; first posterior cell narrowed or closed.

(The *Micropezidæ* and the *Tanypezidæ* are often associated together: Williston, however, divides them.)

Tanypezidæ.

Head concave behind; eyes large; proboscis short; oral vibrissæ absent; genitalia small.

Fairly large flies.

Howlett records the larvæ of a species of *Calobata* living in the roots of a decaying ginger plant.

Psilidæ.

Face bristly above; no oral vibrissæ; antennæ generally long; no pre-apical bristle; subcosta absent; first posterior cell wide open.

The flies are rather small and dark, with a long and narrow abdomen and long legs.

The larvæ have been found in plant galls and in the roots of plants. A few are recorded as pests.

Psila rosæ, the carrot fly, is the most important. The fly is black and shiny, with iridescent wings, about one-sixth of an inch long. The flies emerge in the spring from pupæ and lay eggs in the soil close to turnips or carrots. The eggs hatch in twelve to nineteen days. The first-stage larva has a pair of strong chitinized processes at the posterior extremity, which are lost after the first moult. The larvæ mine the root,

at first keeping near the surface, but later boring near the centre, leaving the walls of the galleries stained a rusty brown. They are full fed in four to five weeks, and they then pass out into the soil to pupate. The fly emerges after a variable period of a month upwards, some hibernating in this state. There are two generations a year in this country. (The above is an extract from K. M. Smith, December 15, 1921, in the *Fruit-grower*.) Sorauer (1913) gives eight days as the pupal period, and several generations per annum in Germany. The most successful remedies as found by Smith was 1 per cent. of green tar oil in precipitated chalk, spread on the soil close to the plants, soon after they show through (in the case of early-sown carrots); and 1 per cent. of creosote applied in the same way for late-sown carrots.

Ortalidæ.

Signal-flies.

Upper fronto-orbital bristles only; no oral vibrissæ; subcosta present; only middle tibiæ spurred; no pre-apical bristles.

Rather small to moderately large flies. As a rule the wings are ornamented and the legs short and stout. The male has five abdominal segments and a long rolled-up penis, and the female has six abdominal segments and a three-jointed horny ovipositor.

Ortalids may be found about meadows, but little appears to be known of their habits and histories. Some species have the habit of walking about on the leaves of plants, waving their banded wings slowly as if sending semaphore signals. Howlett (1909) thinks they may be similar to those of *Oscinidæ* and *Trypetidæ*, and that the larvæ mostly live in the stems and leaves of plants. Some live in the frass of boring insects.

Two species are recorded as pests, *Tritoxa flexa*, the black onion-fly, and *Chætopsis æenea*, on cereals, both from the United States.

In *Genera Insectorum* Handel lists the *Pyrgotinæ*, Fasc. 79 (1908), *Ulidiinæ*, Fasc. 106 (1910), and *Platystominæ*, Fasc. 157 (1914).

Trypetidæ.

Fruit-flies.

Lower fronto-orbital bristles present and close to the eyes; no oral vibrissæ; subcosta present, often indistinct; pre-apical bristles absent; wings usually ornamented; anal cell usually drawn out to a point.

Rather small flies, as a rule with dark bands or patches on the wings. When at rest or walking on a leaf, the wings are held nearly straight out on either side.

They are to be found in all parts of the world but their importance is much greater in tropical and subtropical regions than in temperate zones.

The flies are mostly very fond of fruit and lay their eggs under the skin. The maggot mines the fruit and grows larger at its expense. They may pupate within the fruit, or drop to the ground to do so, according to species.

Some Trypetids are remarkable in that the males of some forms are strongly attracted by certain substances. Howlett (1912, 1915) found that not only were *Dacus* attracted by oil of citronella, but that certain species were attracted by different constituents of the oil and could be separated by baits of iso-eugenol and methyl-eugenol. The males of *Ceratitis capitata*, the Mediterranean fruit-fly, are strongly attracted by kerosene oil.

The most important economic species belong to the genera *Acidia*, *Rhagoletis*, *Dacus*, *Ceratitis*, *Anastrepha*, *Carpomyia* and *Trypeta*.

Acidia heraclei, the celery-fly, is a pest in Europe and Asia Minor on celery, parsley, and parsnips, and may also attack the Jerusalem artichoke. The fly lays its eggs under the epidermis of the lower side of the leaves (Taylor, 1918). In six to fourteen days the larvæ hatch out and live for fourteen to nineteen days, mining the leaves and eating out the soft spongy tissue. There are two broods in the year, the pupal period of the first brood being twenty-seven days and of the second brood up to ten months. The fly hibernates in the ground as a pupa in this country (Gardner, 1921). In the

South of France it is the adult which hibernates (Feytaud, 1915); the pupa being found on the leaves. The alternative food-plants are *Umbelliferæ* and *Compositæ*. Control measures recommended are to dust with soot or powdered lime; to spray with quassia or paraffin emulsion; and to burn all leaves showing blisters.

In the genus *Rhagoletis* are *R. pomonella*, the apple maggot or railroad worm, confined at present to North America, and three forms on cherries—*R. cerasi* (Europe), *R. cingula* and *R. fausta* (both North America). The eggs are laid in the fruit, which after a while drops off. Control measures include spraying with molasses and lead arsenate and destroying fallen fruit.

Most, if not all, the species of *Dacus* have some economic value as pests.

Dacus oleæ, the olive-fly, is tropical and subtropical, and is found in Spain, Italy, France, N. Africa, and India. Fletcher (1917) noted that their presence in N.W. India on wild olives was a fact of some importance, since some people there were beginning to introduce the European olive.

Enormous damage has been done to olive groves by this pest: Rizzo estimated the loss of crop in Italy due to this fly to be £8,000,000 in 1915.

The life-history of the fly follows the usual course. Oviposition takes place in the fruit; the larva mines it, and, the fruit presently falling off, the larva pupates in the soil.

The most successful method of combating the olive-fly appears to be the system devised by Lotrionte. Traps made of interlaced twigs across a V-shaped piece of metal sheeting are tied to the trees, usually one to each, and a concoction of glucose syrup (50–60 pts.) arsenite of lead (2 pts.), boric acid (2 pts.) and sodium borate (2 pts.), is sprayed on to the twigs. About one and a half ounces is applied to each trap three times or so during the development of the fruit.

The flies are parasitized by Chalcids and Ichneumons.

Dacus cucurbitæ, the melon-fly, is a serious pest of *Cucurbitaceæ*, and has also a tropical distribution. In Hawaii it causes great damage to all sorts of Cucurbitaceous fruits, and tomatoes as well (Westgate, 1918). The estimated cost of damage in

1914 was $1,000,000 for the year. Its life-history in Hawaii, according to Severin and Hartung (1914), is :

Incubation period	1¼–1½ days.
Larval period.	3¾–11 ,,
Pupal period	10–14 ,,

Egg-laying does not begin till fourteen to seventeen days after emergence. In this period, feeding apparently is necessary for the ripening of the gonads. According to Back and Pemberton (1917) a female may lay up to 1,000 eggs, and there are 8–12 broods per annum.

Of the genus *Ceratitis*, *C. capitata*, the Mediterranean fruit-fly, is one of the most important pests in the world. It has been the cause of enormous loss and of a considerable amount of legislation. It is found in E., W., and S. Africa, S. Europe and the Mediterranean coast, Australia, S. America, Bermuda and Hawaii. It has not yet got a footing into N. America, on account of the stringent regulations in force, but it is being constantly intercepted by the authorities in California from Hawaii and elsewhere.

The fly attacks an extraordinary variety of fruit, both hard and soft, cultivated and wild, and this fact makes it very difficult to deal with. It has been most successful in establishing itself in Hawaii, where it costs millions of dollars a year. All sorts and kinds of methods have been tried to cope with it, with little or no success. Paraffin traps caught large numbers, but as they were almost exclusively males, the traps did little or no good. Natural enemies have now been found and thousands of Chalcids and Braconids are released every year now in Hawaii; it is hoped that in this way the pest will be brought within reach of artificial methods of control.

Rhopalomeridæ.

Antennæ short ; arista bare or plumose ; no oral vibrissæ ; femora thickened ; hind tibiæ often dilated.

Flies one-quarter inch to half-inch long, found in South America.

They are of no economic importance.

Sapromyzidæ.

No oral vibrissæ ; subcosta present.

Shiny yellowish or black flies, rarely more than one-third of an inch in length. The female has a long, slender ovipositor. The wings are sometimes clouded.

The larvæ live in decaying vegetable matter. In form they are slender, roughened by small bristles. The penultimate segment has four conical processes, and the terminal one two three-jointed processes, between which is the stigmatic tube.

Agromyzidæ.

Arista bare or pubescent ; oral vibrissæ usually present ; subcosta indistinct or absent.

Minute to small blackish or greyish flies, to be found all over the world.

The larvæ creep about like those of geometrid moths. Most of them mine the stems or leaves of plants, but a few live in the galls of other insects. Howlett (1909) records a species of *Leucops* as being predaceous, and according to Essig (1915) *Cryptochætum iceryæ* is parasitic on *Icerya purchasi* in California.

Several species are recorded as pests on grasses (e.g. *Agromyza atra*), on *Leguminosæ* (e.g. *Agromyza phaseoli* on beans in N.S.W.), on *Cruciferæ* (e.g. *Phytomyza affinis* and *A. diminuta*), and on asparagus (*A. simplex*). C. T. Greene (1914) gives an account of *Agromyza pruinosa*, which mines the cambium of birch trees in America.

Oscinidæ.

Arista bare or slightly pubescent ; oral vibrissæ rarely present ; frons bristly above or altogether bare ; median and anal cells absent.

Small to minute flies, common about grass and meadow land. Usually they are coloured yellow or yellow and black, which serves to distinguish them from the *Drosophilidæ*.

The larvæ live mostly in the stems of grasses, but some are found mining the leaves of sugar and beet, and others in galls on grasses.

Several pests are recorded from this family, chiefly on cereals; but *Oscinis theæ* in India mines the leaves of tea and another attacks coffee in Java and Ceylon.

Oscinella frit causes much damage to rye, oats, barley, wheat, maize and grasses. Most damage is done to oats in Europe and to winter wheat in the United States.

The flies emerge some time between the end of March and mid-June: chiefly mid-April to mid-May in this country. Twenty to seventy eggs are laid by the female on the stems, or on the leaves near the stems. In three to seven days they hatch, and the larvæ eat away the heart of the plant, causing the stem above to wither away. In two to five weeks they pupate, and in eight to fourteen days the second brood appears (June, July). The eggs of this brood are laid in the sheaths of the ears, on the panicles or on wild grasses (Collin, 1918).

There are usually three broods in the year, the last appearing any time from August to December. In S. Russia four and five broods have been recorded, and also from N. America (Aldrich, 1920).

The best preventive measures seem to be late winter sowing and early spring sowing, with a top dressing of sodium nitrate when the plants are through.

Chlorops tæniopus, the gout-fly, attacks wheat, rye, and particularly barley in Europe and has a history similar to the frit-fly. *Meromyza* and *Scaptomyza* occur in the United States on cereals.

Chloropisca circumdata also attacks cereals in Europe. Occasionally it is a nuisance in country houses, swarming on the ceilings of the topmost rooms. They come in when the weather begins to get chilly in the autumn, but after a time they disappear: they do not hibernate in the house.

There is a species in India, *Siphonella funicola*, the eye-fly, which has a habit of flying just in front of one's eyes. In South America and Fiji a similar form gets into the eyes of domestic animals, and may be a factor in spreading eye disease there.

Drosophilidæ.

Arista plumose or pectinate; oral vibrissæ present; subcosta absent or indistinct.

Minute to small flies. The body is bare, except for bristles on the front of the head. Several forms have red eyes. Many of them are attracted to decomposing fruit, wine, vinegar, etc. Eggs are laid in rotten fruit and in decomposing matter of all kinds. *Drosophila melanogaster* is a minor pest on grapes.

A large amount of work has been done in the United States on *Drosophila ampelophila* by Morgan and others with regard to Mendelian heredity. The small number of chromosomes, and the ease with which this fly presents a large number of mutations, make it particularly suitable for this work.

Sepsidæ.

Head rounded; proboscis and antennæ short; subcosta present, or fused with R_1; middle tibiæ with spurs; abdomen narrowed forward.

Fairly small flies, yellowish or shining black. The abdomen of the female is pointed at the posterior end, while the hypopygium of the male is prominent and broad.

They are found about decaying matter of all kinds, and about foods of a fatty nature. The eggs are laid in such situations, and the larvæ feed upon the material in which they hatch.

Piophila casei is a common species in temperate climes, and is very partial to cheeses, especially the stronger kinds. The flies are black, about a sixth of an inch in length, and may be seen stalking slowly and deliberately over the surface of a cheese. The larvæ have the habit of "jumping," by curving themselves, fixing their mouth-hooklets in notches at the posterior end, straining and letting go sharply. This habit has gained for them the name of "cheese hoppers" or "jumpers." These flies may breed in rotten fungi, or dead adipose tissue, and are found near accumulations of garbage. They have been known to cause enteric myiasis, causing lesions in the

intestines of the dog. A case of nasal myiasis has also been reported (Melander and Spuler, 1917).

Ephydridæ.

Arista bare, pubescent or pectinate; no oral vibrissæ; no anal cell; middle tibiæ spurred; no pre-apical bristles.

Small to minute flies, bare or nearly so, and nearly always black. They are found about meadows, marshes, etc., though one form, *Brachydeutera argentata*, runs about on the surface of water.

The larvæ are to be found in stagnant water, in decaying vegetable matter, under bark, and sometimes in strongly salted water. The adults are predaceous on other insects.

Hydrellia griseola is recorded as a pest of oats, in which it mines the leaves, and of other cereals and grasses.

V. Becker, *Berlin Ent. Zeit.* (1896).

Phycodromidæ.

Oral vibrissæ indistinct; frons and face bristly; subcosta present; legs stout, each tibia with a spur and a pre-apical bristle; mesonotum, scutellum and abdomen flat.

Small, dark flies, found on the sea-shore, about seaweed, etc.

Heteroneuridæ.

Antennæ porrect; arista bare, pubescent or plumose; oral vibrissæ present; frons bristly; post-vertical bristles divergent.

Small flies, with elongate wings, found in woods and forests, about shaded brooks and marshy places.

The larvæ are found in decaying wood and under bark. The mouth-hooklets of the larva are very small. They have a way of "skipping" about like the larvæ of *Piophila*.

The puparia have two horns on the posterior segment.

Sciomyzidæ.

No oral vibrissæ; post-vertical bristles divergent; subcosta present; pre-apical bristles present.

Brownish flies, usually with markings on the wings.

The larvæ are aquatic. The last segment has six or eight fleshy processes.

The adults are found in moist localities.

Helomyzidæ.

Oral vibrissæ present; subcosta present; costa pectinate; tibiæ with spurs and pre-apical bristles.

This is rather a small family. The flies are found in shady and damp places, and occasionally on windows. Some live in caves and burrows.

The larvæ are somewhat cylindrical but narrower in front than behind. The mouth-hooklets are large and pointed. They feed on animal and decaying vegetable matter.

Celyphidæ.

Antennæ long; arista flattened; scutellum very large.

These flies are easily recognized by the remarkable development of the scutellum, which may cover the abdomen completely, hiding the wings when at rest. They are generally found among grass.

They are of no economic importance.

Borboridæ.

Antennæ short; arista dorsal or terminal, bare or pubescent; oral vibrissæ present; subcosta absent or incomplete; hind metatarsi usually dilated.

Small to minute dark flies, usually found about decomposing organic matter, in which the larvæ live.

They are of no importance economically.

Diopsidæ.

Head produced into lateral processes, each bearing an eye; no oral vibrissæ; front femora thickened.

Small, bare flies, easily recognized by the peculiar shape of the head. They have a restricted tropical distribution, and have been found in India, Africa, and North America.

Little is known of these flies, except *Sphyracephala hearseiana*, a short account of which is given by Sen (1921). He says that these forms are found in certain parts of India, where they congregate in large swarms on rocks or the like in damp and shady places. Their structure suggests a predaceous habit, but this has not yet been proved. In captivity the incubation period of the egg was found to be four days, the larval period seven days, and that of the pupa ten days. The structure of the larva indicates a semi-aquatic mode of life.

They are of no economic importance.

Cordyluridæ.

Front with bristles; eyes widely separated in both sexes; squamæ present, but small; subcosta present; costa pectinate or not, but never with a spine where R_1 runs into the costa; abdomen with more than four visible segments.

The larvæ are found in dung (mostly the sub-family *Scatophaginæ*), in wet places near water, and in the stems of water plants. Williston, 1908, records a species of *Clidogastra* as a Noctuid parasite.

The adult flies are found in moist places and about excrement, and are predaceous. *Scatophaga stercoraria*, the yellow dung-fly, was recorded by Hewitt, 1914, as attacking Muscids. According to Cotterell, 1920, it has attacked the common house-fly and blow-fly; in suitable circumstances it might be a very efficient check on these flies.

(ii) *Calyptratæ.*

Squamæ well developed ; eyes of the male holoptic ; subcosta distinct ; transverse suture complete.

Anthomyiidæ.

Arista plumose, pubescent or bare ; the first posterior cell broadly open.

Small to moderately large flies, usually of a dull, dark colour. The males are frequently holoptic, but all have the eyes closer together than the females, and some have the genitalia well developed. They can be recognized from the other calyptrate flies by the widely open first posterior cell.

The majority lay their eggs in decaying vegetable matter, dung, etc., and the larvæ feed on this material. The remainder show considerable variety of habit, however, for some maggots feed on roots, some are leaf-mines, a few are found in the nests of bees, one or two are parasitic on locusts, some of the genus *Mydœa* in Africa are carnivorous (Rodhain and Bequaert, 1916), and Keilin (1919) states that several forms cause subcutaneous myiasis in birds.

Fannia canicularis is usually known as the lesser house-fly. It is smaller than the common house-fly, which belongs to the *Muscidæ*. It is usually unobtrusive and flies aimlessly about in the air ; but given the chance it may become dangerous in the dissemination of intestinal disease, as it did in Gallipoli during the Great War.

Some species of *Fannia* are from time to time recorded as causing myiasis in the urethra and alimentary canal of man.

Several forms are pests which trouble the market-gardener and farmer.

The onion-fly (*Phorbia cepetorum*) attacks onions in Europe and America. The fly is dark grey, with four brown stripes on the thorax and black legs. The eggs are laid on the plant just above the ground. The maggots hatch in five to seven days in this country, and then burrow into the bulb, where they live for thirteen to fifteen days. They then pupate, the pupal period being from ten to twenty days. There are

several broods during the year, and it passes the winter as a pupa in the soil or in stored onions.

Pegomyia betæ attacks mangolds and beet. The flies are in evidence from March to June in this country.

One to four eggs are laid on the under-surface of the leaf. The maggots hatch out in about five days and mine the leaf, eating the soft tissue for about a month. They pupate in the leaf and the flies emerge in ten days. There are three or more broods in the year, and hibernation takes place in the pupal stage.

Chortophila brassicæ, the cabbage-root fly, is about a quarter of an inch long, and of an ashy grey colour. The flies first appear in April and May, and the females lay their eggs in the soil, close to the cabbage plants. The eggs hatch in a few days. The maggots are whitish, and attack the rootlets of the plant. In about three weeks the maggot is fully grown, ceases to feed, and pupates in the earth.

There are two and sometimes three generations in the year; the winter is passed in the pupal stage.

As a preventive against the attacks of this fly, a mixture of green tar oil and earth, etc., in the proportion of 1 to 100, is cast on the soil when the cabbages are planted.

Hylemyia coarctata (the wheat-bulb fly), in Europe and N. Asia, is also a pest of importance.

Muscidæ.

Arista plumose or pectinate; first posterior cell narrowed or closed; base of abdomen without macrochætæ.

Rather small to rather large flies, usually of a dull colour, but sometimes metallic blue or green. The first posterior cell is usually closed or nearly so, but it may be rather widely open in some genera, in which the median vein has a slight forward curve at the end. The males are holoptic and the females dichoptic.

They are a very cosmopolitan group on the whole, the common house-fly probably being the most ubiquitous of all insects.

Many lay their eggs in dung, vegetable refuse, etc.; the bluebottles and greenbottles usually oviposit on meat and

decaying animal matter, but some forms occasionally do so on live animals. For instance, *Lucilia argyrocephala*, one of the greenbottles, attacks birds and mammals, including man, in the Congo in this manner (Roubaud and v. Saceghem, 1916)—and other species of *Lucilia* have been recorded laying their eggs on young birds, and in open sores and wounds. Species of *Chrysomyia*, the screw-worm fly, in North America, behave in the same way, but in this case it has become a fixed habit. Further specialization in this direction is shown by *Cordylobia* in Africa and *Dermatobia* in America, the maggots of both of which burrow into the skin. The larva of *Auchmeromyia*, the Congo floor maggot, is remarkable for the fact that it sucks human blood, a habit similar to *Protocalliphora azurea*, the larva of which sucks the blood of birds (Coutant, 1915).

From a medical point of view the family is an important one.

FIG. 154.—Larva of *Musca domestica*.

as. = anterior spiracle. *ps.* = posterior spiracle. *bh.* = buccal hooks.

Various forms may cause myiasis, as mentioned above. *Musca domestica*, the common house-fly, is capable of spreading such diseases as typhoid, summer diarrhœa, cholera, amœbic and bacillary dysentery, diphtheria, ophthalmia, and poliomyelitis, and is suspect in the case of others. Much has been written about this little insect, and its habits have been advertised extensively with a view to reducing the pest to insignificant proportions—but it is so prolific and adaptable, and the public so averse to stirring itself in its own interest and that of its neighbours, that little or no effect has been achieved. The main problem is to attack the breeding-places and try to prevent breeding or to destroy the insect in its early stages by means of poison. What a co-operative campaign can do is shown by the fact that the flies in Mesopotamia during the war were controlled by careful sanitation, the destruction of maggots in the latrines,

and by trapping the adult flies on a sodium arsenite poison trap. In houses, the wire balloon trap baited with banana is a convenient trap ; or they may be poisoned with a 2 per cent. formalin solution, made up with a little lime water, adding milk or a crust as a bait. One per cent. sodium fluoride solution may be used in the same way, in place of the formalin, and is very deadly.

Blow-flies should be screened from meat in some way. This

FIG. 155.—Wing of *Pollenia rudis*.
1st pc. = 1st posterior cell (closed).

is usually done in houses, but the butchers' shops in this country are often a repulsive sight in hot weather, when the flies are allowed free run of the meat.

One of this group, *Lucilia sericata*, the sheep-maggot fly, does considerable damage to sheep by causing sores, inflammation, discoloration of the wool, and general loss of condition. In Australia, a number of species have acquired this habit

FIG. 156.—Wing of *Stomoxys calcitrans*.
1st pc. = 1st posterior cell (narrowed).

of ovipositing on sheep, and these include *Muscina stabulans*, and species of the genera *Calliphora*, *Lucilia*, *Chrysomyia* and *Pollenia*.

The habits of Muscid flies are multifarious. Some, for instance, infest country houses and large buildings in considerable numbers in the autumn and spring.

Pollenia rudis, the cluster-fly, is one of these. It is a little

larger than *M. domestica*, but can easily be distinguished from it, as it has a pale golden pubescence; and when at rest its wings are folded over one another. Keilin states that it lays its eggs in the soil, under grass. The maggots, if fortunate, find their way into an earthworm of the genus *Allolobophora*, and they live there till full-grown, and then pupate in the soil. In the second instar, the maggot makes its way to the front end of the worm, and extrudes its hind segments so as to bring its spiracles into contact with the air. This author, describing his researches in France, gives one generation per annum, the winter being passed in the larval stage. In America, apparently, there are three or four generations in the year (Webb and Hutchison, 1916). These writers do not say how the winter is passed, but state that they could find no hibernating larvæ. This remarkable life-history bears a close resemblance to that of the Tachinids. The adults also hibernate in masses behind pictures, shutters, etc., in cracks and round window frames, in the upper rooms—usually or preferably uninhabited ones. When the warm weather arrives, they wake up and worry the inmates with their active presence.

Associated with *P. rudis* are often found two other species—*Musca corvina*, resembling *M. domestica*, except that the abdomen of the male is yellow, with a black stripe down the middle—and *Pyrellia eryophthalma*, a metallic bluish-green fly, rather smaller than the common greenbottle *Lucilia cæsar*. Both these forms may appear in large numbers, especially the latter. Both sexes are present in the three associated forms.

Many adult Muscids have their mouth-parts adapted for sucking blood. The genera *Stomoxys* and *Hæmatobia* are common in all latitudes. *Stomoxys calcitrans* is the commonest of these. It breeds in horse-dung and damp straw, especially oat straw. In size and general appearance it resembles the house-fly, but when at rest its proboscis can be seen projecting forward beyond the head, and the first posterior cell of the wing is rather broadly open. The favourite place for biting seems to be the ankles. So far it has not been proved to convey any disease. In all blood-sucking Muscids, both males and females suck blood.

The chief blood-sucking group are the tsetse flies, constituting

the sub-family *Glossininæ*. They are confined to Africa and Southern Arabia, although it is interesting to note that fossil forms have been discovered in Colorado (Cockerell, 1918). They are an important economic group, since they transmit a number of trypanosome diseases, including sleeping sickness and nagana. Usually they inhabit damp and shady places, near water. The flies do not lay eggs, but full-grown larvæ, which they drop one at a time on the ground while in flight. The larvæ bore into the ground and pupate at once.

The tsetse flies prefer black to other colours, and do not come to white, so that white clothing should be worn in fly

Fig. 157.—Wing of *Polietes lardaria*.
1*st pc.* = 1st posterior cell.

belts ; the flies can be trapped on a small scale on sticky black surfaces. Where practicable, the clearing of scrub for thirty or forty yards from water has been beneficial, as the insects as a rule do not fly more than thirty yards from the water ; they may, however, follow men and animals away from the water for much greater distances.

References.—E. E. Austen, *Monograph of the Tsetse Flies* (1903) ; C. G. Hewitt, *The Housefly* (1910) ; G. S. Graham-Smith, *Non-blood-sucking Flies* (1914) ; E. E. Austen (1922).

Sarcophagidæ.

Flesh-flies.

Arista plumose half-way, or a little beyond, the distal portion being bare ; first posterior cell narrowed or closed.

Medium-sized to rather large grey flies, resembling the *Muscidæ*, from which they are distinguished by the arista. Sometimes the hypopygium of the male is well developed. The eyes are often red.

The adults are found about decaying vegetation, animal and fæcal matter, and also fruit. The larvæ live on such material, but some are parasitic in snails and in insects; they have also been known to cause myiasis in man and other animals.

According to Kelly (1914) six species of *Sarcophaga* are parasitic on grasshoppers, *S. carnaria*, the common form in this country, being the only one of the genus which is not parasitic. This authority gives an account of *S. kellyi*, in which he says that it attacks grasshoppers, knocking them down whilst in flight, and managing to deposit on the wings or abdomen of the locustid one or more larvæ in this short space of time. The larvæ enter the body of the grasshopper at the base of the wing or between the segments of the abdomen. They take ten to thirty days to mature, and they then leave the host to pupate two to six inches deep in the soil. Their sight does not appear to be very acute, for they larviposit indiscriminately on any insect, and even on balls of paper thrown into the air. They may also larviposit on the nymphs of grasshoppers, as these sit on blades of grass during the hardening of the chitin.

There are five or six generations a year.

They are themselves parasitized by several Chalcids.

Tachinidæ.

Arista bare and three-jointed; first posterior cell narrowed or closed; macrochætæ on the basal portion of the abdomen.

This is a very large family of bristly flies, usually found about flowers on which they feed. So far as is known, the larvæ are all parasitic on other insects, chiefly *Lepidoptera* and *Hymenoptera*. Fabre gives a charming account of the relations between a species of *Miltogramma*, and *Bembex*, a fossorial wasp.

In the aggregate, the *Tachinidæ* must exert a very powerful check on insects in general, and so help to keep them within reasonable limits. Several are important in being checks on economic pests.

The following few examples are interesting as showing the wide range of method adopted by the Tachinidæ. Thus they may be oviparous or larviparous, and may lay eggs or young maggots on

either larvæ or adult insects ; or they may lay their eggs in such places as may bring their victims in close contact with them.

Bucentes geniculata parasitizes the larvæ of *Tipula paludosa* largely ; also *T. oleracea*, and probably others. The fly is rather small and dark, with strong abdominal bristles. It is widely distributed in this country.

The flies emerge in April and May, and die off in June. From mid-June and onwards from 16 to 40 per cent. of Tipulid larvæ were found infected one year by young *Bucentes* maggots. Any number up to nine were found in each leather-jacket. The larval period does not appear to be more than five weeks, and the parasites then leave the host and pupate at a depth of 2–3 inches in the soil, though sometimes the parasites remain attached to the tracheal trunks. The pupal period lasts about seventeen days. The adults lay eggs, and the larvæ which find hosts spend the winter in them. Nielsen (1918) however states that they hibernate in the pupal stage. There are two generations a year.

The above extract is made from Rennie and Sutherland (1920).

Embiomyia calosomæ attacks Calosoma beetles. The latter are employed extensively in America for combating the Gipsy and Brown-tail moths, on which they prey.

The flies emerge in May and June, and lay from one to four eggs on some part of the surface of the adult beetles, but as many as ten eggs on one beetle have been recorded. The eggs hatch in from three to twenty-four hours, and the larvæ bore into the host and take nine to twelve days to develop. They may pupate inside the beetle, or externally between the elytra and the abdomen, above or below the wings. The pupal period lasts nine to fifteen days.

The flies of the second generation issue in July and August. Eggs are again deposited on the beetles, and the larvæ hibernate in the beetle after the first moult. In a favourable season there may be a partial third generation.

The above account is taken from Collins and Hood (1920).

Howard and Fiske (1912) give an account of *Blepharipa scutellata*, the chief Tachinid parasite of the Gipsy moth. The fly lays its eggs on the leaves of the food-plant of the caterpillar, which eats them. Those escaping mastication pass

into the alimentary canal, and embed themselves in the tissues of the host, causing a sort of gall formation. After a moult the larva changes its position and seeks one of the spiracles, to which it applies its posterior end, thus bringing its own spiracles in contact with the air. The activities of the third instar are not given, but it is stated that the parasite waits until the host pupates before devouring it to death. The parasite pupates in the earth, and the whole cycle occupies ten to eleven months.

The same authors give an account of *Compsilura concinnata*, which attacks impartially both the Gipsy moth and the Brown-tail moth, as well as a large number of other *Lepidoptera*. There are fifty-eight European hosts recorded, and a list of twenty-three American ones given by Culver (1919) probably leaves a good margin.

The method of attack of this fly differs from *B. scutellata*. It inserts its ovipositor under the skin of the caterpillar, and extrudes tiny maggots, which develop quickly for about two weeks. After the first moult, they migrate to the posterior spiracles. When they come out to pupate, they do so either in the earth at the foot of the tree on which their hosts lived, or behind the bark; but some may be found in the cocoons of the moths. The pupal period lasts about a week in the earth, but only a couple of days or so on the tree. The adults attain maturity in three or four days. Thus the whole cycle is completed in about a month. Culver (1919) gives three generations a year. Hibernation takes place in the larval stage.

In Canada large numbers are reared and distributed yearly. In the entomologist's report for 1917, for example, 15,725 puparia were reared from 78,484 caterpillars of the Gipsy moth, which were collected from forty-five different places.

Dexiidæ.

Arista bare, pubescent or plumose, two- or three-jointed; abdomen with bristles along the dorsum; legs long and bristly.

Small to medium-sized flies, resembling the Tachinids both in appearance and habits. So far as is known they are entirely parasitic on insects and snails.

The eyes of the males are close together, those of the females more widely separated.

ŒSTRIDÆ.

Bot-flies. Warble-flies.

Antennæ short, small and inconspicuous; oral opening small, mouth-parts small and rudimentary; first posterior cell narrowed or closed; discal cell sometimes absent.

Rather large, hairy flies, with large heads, the lower part of which is rather swollen.

The larvæ are all parasitic on mammals, and eggs are laid on the hairs or skin of the animal attacked. Each species has its own particular host. The maggots may infest different parts of the body, e.g. *Gastrophilus equi*, the horse bot-fly, lives in the stomach; *Œstrus ovis*, the bot-fly of the sheep, chooses the cavities of the nose and pharynx; while *Hypoderma bovis*, the ox warble-fly, travels about in its host, but ends finally in the skin of the back.

The history of the last-named is as follows:—The eggs are laid on the hairs of the hind-leg, chiefly below the hock. The spiny maggots hatch in four or five days and bore into the skin, and after three or four months' wandering reach the œsophagus, where they remain for a year or so. They then migrate to the skin of the back, where they feed on the fluid arising from the inflammation. The posterior end is pushed through the skin, bringing the spiracles into contact with the air. In the early spring they come out, fall to the ground, and pupate for about six weeks.

The damage done to the hides in this way is very considerable, but no satisfactory method of combating the fly has as yet been found.

Œstrus ovis deposits larvæ in the nostrils of sheep and goats, and the maggots live in the nasal sinuses, but come out to pupate. A mixture of white-pine tar oil and eucalyptus should be smeared over the bottom of the salt-trough, so that the sheep get some on their noses. This is said to keep the fly away.

The family were listed by Barr as a sub-family of *Muscaridæ* in 1906 (*Gen. Ins.* 43).

(c) PUPIPARA

Medium or small flies with a leathery integument, winged or wingless, generally parasitic.

Hippoboscidæ.

Antennæ inserted in depressions near the mouth, apparently one-jointed; the proboscis sheathed in the palps; head and thorax flattened; halteres reduced; coxæ broadly separated; claws strong and sometimes toothed; wings absent or present, the veins approximated to the front of the wing, where they are well marked, the rest of the wing hyaline, with faint, oblique veins showing.

The flies are leathery and brown, with strong legs. The adults are all parasitic on birds or mammals. They include *Melophagus ovinus*, the sheep- "tick" or "ked," and *Hippobosca equina*, the horse or "forest" fly: they are abundant in the tropics on dogs and horses.

Fig. 158.—*Stenopteryx hirundinis.* (× 4.)

The sheep-tick passes its life on the host. Swingle (1913) gives the following data:—The larva is born mature and pupates in twelve hours. The pupal stage lasts nineteen to twenty-three days in summer and at least nineteen to thirty-six in winter. Pairing takes place three to four days after emergence, and the birth of a larva ten to twenty-seven days after. The female produce ten to twelve young in four months.

According to Nöller (1919), this insect transmits sheep trypanosomiasis. He considers the parasite as quite distinct from *Crithidia melophagi* which *M. ovinus* is known to harbour.

Nycteribiidæ.

Head at rest folded back on the thorax; antennæ two-jointed, short and bristly; eyes vestigial; wingless.

The flies are small, with the legs long and held like those of a spider. All are parasitic on bats. They cling to their host so that their dorsal surface is in contact with the skin of the bat, and feed in this position on its blood. There are several species, many of which are described by Ferris in vol. 27 of the *Entomological News* (p. 436). According to Scott (1916), they are not confined to any one species of bat, but, broadly speaking, some prefer the fruit-eating bats, the others the insectivorous forms.

The mature females give birth to full-grown larvæ, one at a time, and leave the host to do this on some smooth and dry surface near the host. The larva is motionless, and is made to adhere firmly by the mother, which stands over it and pats it against the surface with her thorax; it remains stuck hard by the gummy secretion expelled by the mother during the extrusion of the larva. The act accomplished, the fly scuttles back to the host. The larvæ are soft and rounded, and whitish in colour. The exposed part of the skin hardens and darkens in about half an hour, but the remainder takes considerably longer (Scott, 1916).

Rodhain and Bequaert (1915) give a similar account for *Cyclopodia*. They state that unless the adults find hosts within forty-eight hours, they die; also that copulation takes place on the host. (See also Urich and Scott, *P.Z.S.* June, 1922.)

Streblidæ.

Antennæ two-jointed, inserted in a pit; palpi short, broad and projecting.

Like the foregoing family, they are parasites on bats, but little more appears to be known about them.

For convenience, another bat parasite may be described here. It is less like the Nycteribiid than the Streblid, and

has as yet not definitely been allocated to any family. The following is an abstract from Muir's account in 1911.

Ascodipteron speiserianum is found in the Dutch East Indies. The males and females hatch out as normal winged adults. The female, on finding a host, burrows into the skin at the base of the ear "and then casts her legs and wings; her abdomen then develops to an enormous extent, and entirely envelops her head and thorax, so that she appears as a bottle-shaped grub without legs or head." The larvæ are born fully grown and fall to the ground, where they pupate. The pupal period is thirty to thirty-one days.

Braulidæ.

Minute, wingless flies, of about 2 mm. in length, found on bees. The last tarsal joint has a pair of combs.

There is only one species, *Braula coeca*. According to Skaife (1921) it is neither parasitic nor pupiparous. He gives the following life-history:—Eggs are laid haphazard over the brood-combs. They are minute and difficult to see, being covered with wax. On either side of the egg is a reticulated flange running lengthways, the two nearly meeting at either extremity. The larva on hatching makes its way to a cell containing the grub of a bee, and feeds on the food already stocked there. It has a typical muscoid form, and is metapneustic. The puparium is white and the pupa may be seen through the transparent larval skin. On emergence, the adult makes its way on to a bee.

The food of the adult appears to be honey. This it obtains from the mouth of the bee, which it stimulates in some way to release a drop.

Skaife, "*Braula coeca*"—*Roy. Soc. S. Af.*, vol. x, No. 1 (1921).

SIPHONAPTERA

Antennæ three-jointed, in a groove; eyes simple when present; mouth-parts adapted for piercing and forming a tube for the suction of blood; the thorax with three movable segments; all coxæ and epimera of metathorax well developed; wings absent; metamorphosis complete.

Fleas are small, bilaterally flattened insects, well known to the layman on account of the irritation of their bite and their ubiquity. They lead a more or less parasitic existence on warm-blooded vertebrates, none being exempt from their attentions, unless it be the monkey tribe.

Fig. 159.—*Xenopsylla cheopis* ♂. (× 25.)

For the most part they are about one-eighth of an inch in length, though one form from the New World is more than twice this size. In colour they are a chestnut brown.

The body is provided with regular sets of spines pointing backwards, a formation which greatly assists its passage through the hairy or feathery forest of the host's integument. Fleas are renowned for their powers of leaping, and in this respect the human flea, *Pulex irritans*, holds the record in the group.

The head is fixed broadly on to the thorax. In profile it is somewhat triangular, but rounded from front to vertex. There may be a simple eye on either side, but it is absent in many forms. Above the eye lies the antenna, sunk in a groove pointing downwards and backwards. It has three joints, the third being larger than the other two, rounded and complex.

The mouth-parts include the maxilla, a triangular plate on each side of the oral opening; a pair of four-jointed maxillary

palps; a stiff, piercing labrum; a pair of serrated mandibles, which together with the labrum pierce the skin of the host and form a tube through which the blood is sucked; a median labium, situated posteriorly to the piercing organs, depending from which is a pair of labial palps, consisting of a variable number of joints. The labium and the palps are shaped so that they can sheathe the piercing organs and form the rostrum.

The head is armed with rows of bristles directed backwards. Some forms show a row of short, stout spines on the lower edge of the gena, forming the genal comb.

The three sections of the thorax are not fused together, a rare feature in insects. The pronotum sometimes bears a row of stout spines similar to the genal comb; this is the pronotal comb. The prosternum is pushed forward beneath the head, causing the front pair of legs to appear as if they sprung from the head. The epimerum of the metathorax is strongly developed and is a noteworthy feature of the group.

The abdomen is compactly built of ten segments. The sternite of the first segment is absent, owing perhaps to the great development of the epimerum of the metathorax. On the dorsum of the seventh segment may be one or more pairs of setæ known as the antepygidial bristles, which are used in taxonomy. The last three segments are modified to form the sexual apparatus. The eighth segment is small and may be telescoped under the seventh. The ninth segment bears on each side a sensory plate, the pygidium, behind which, in the male, is a pair of complex claspers. In the female this is replaced by a conical projection, the stylet, which bears upon it a tuft of bristles. The tenth segment is internal.

Alimentary canal. The pharynx has strong muscles attached to it, enabling it to suck up blood through the proboscis. Into the anterior end of the pharynx a tube opens, through which a secretion passes from the four salivary glands and ducts. Behind the pharynx is the œsophagus, communicating with the proventriculus, a somewhat pear-shaped structure, narrow in front and broad posteriorly. This organ is provided internally with a solid basket-work of chitinous rods, directed backwards. It functions as a valve, preventing the contents of the stomach from passing in a forward direction

when the pharynx is at work. At the posterior end of the stomach enter the four Malpighian tubules. From here the short intestine leads to the posterior opening of the alimentary canal; there are six rectal glands attached close to the anus.

The nervous system is primitive in type. The two lobes of the supra-œsophageal ganglion are distinctly separated and joined to the two lobes of the sub-œsophageal ganglion by a commissure on each side of the œsophagus. There follows a chain of three thoracic and seven abdominal ganglia, the first six of the latter being all the same size, and the seventh being larger.

Reproductive system. In the female there are eight ovarian tubes on each side. The spermathecæ are U-shaped and well chitinized, and may easily be seen in cleared preparations. The male has a pair of testes. The penis and sheath are com-

Fig. 160.—Pulicid Larva. (× 18.)
(Based on Bacot and Ridewood.)

plex and curved upwards and backwards, strongly chitinized and easily seen in cleared preparations. The sexes are easily distinguished by the shape of the abdomen, the males appearing to be turned up at the posterior end, the pygidium facing upwards; in the female, the contour of the last few segments curves downwards, the pygidium facing backwards.

Fleas lay their eggs in the neighbourhood of their hosts—in nests, lairs in various localities, on the ground, in dwelling-houses, etc. The eggs are smooth and white. The shell is broken open by the larva by means of a tooth-like process on the head, which structure disappears after the first moult.

The larva is white, legless, and bears long bristles on the segments, of which there are thirteen, in addition to the head. It is very active, and is assisted in locomotion by a pair of downward-pointing processes on the last segment. It feeds on organic debris, which includes the fæces of adult fleas, thus

accounting for the presence of blood in the intestine, so often observed. The internal anatomy closely resembles that of the adult, but there are no rectal glands. The pupa is free, and is found inside a cocoon spun by the larva and covered with grains of sand, etc.

The authority on systematics is Rothschild, and on bionomics Bacot. Their many works should be consulted.

Sarcopsyllidæ.

Chigoes, Jiggers.

Rostrum long, weakly chitinized, the labial palps having but one or two segments ; the genal edge of the head produced downwards behind the maxillæ into a triangular process ; the thoracic tergites together shorter than the first abdominal tergite ; eyes always present.

Many of the forms in this family remain attached to the host after the manner of ticks, the mouth-parts being directed more or less forward. The mandibles are well developed and serrated for such fixation, the labial palps lying upwards in this position. The abdomen of the female swells up considerably, often to an enormous size. In those forms which do not attach themselves permanently to the host, the labial palps point downwards while feeding.

One of the commonest forms is *Dermatophyllus penetrans*, a native of Mexico, West Indies, and tropical South America. It was introduced to Africa during the latter half of the nineteenth century, and has now reached Madagascar.

Pulicidæ.

Fleas.

Rostrum well chitinized ; the labial palps with at least four joints ; the thoracic tergites together longer than the first abdominal tergite.

The fleas of this family need no general description, being known to all as to their size, shape, colour and powers of leaping and biting. One finds them everywhere.

This group contains the great majority of the mammalian and avian fleas. The life-history of all, so far as is known, runs more or less on the same lines.

The eggs are laid in the neighbourhood of the host, in its lair or in its nest. The incubation period may last some days, say from two to ten. The active larval stage is very variable. Bacot (1914) gives the following figures : *Ceratophyllus fasciatus* (the cat-flea), 15–114 days ; *Pulex irritans* (the human flea), 9–202 days ; *Xenopsylla cheopis* (the rat-flea), 12–84 days ; *Ctenocephalus canis* (the dog-flea), 11–142 days. Cold has considerable effect in protracting the active life, but this author points out that the individual variations in longevity from the same batch of eggs is very marked.

When the cocoon is spun there is a resting stage in the larval condition before pupation, and there may also be an imaginal resting stage before emergence. Bacot (ibid.), gives the following figures for the total duration from spinning the cocoon to emergence : *P. irritans*, 7–239 days ; *X. cheopis*, 7–182 days ; *Ct. canis*, 7–354 days. The cocoon is a protection both against drought and against wet. The same authority gives the following figures for maximum longevity in the adult : *C. fasciatus*, 106 days (fed), 95 days (unfed) ; *P. irritans*, 513 days (fed), 125 days (unfed) ; *X. cheopis*, 100 days (fed), 38 days (unfed) ; *Ct. canis*, 234 days (fed), 58 days (unfed.) Thus the total length of life from the egg to the death of the adult may be several months, even if the adult can get no food.

As a rule fleas prefer one species of host to feed on ; but in case of necessity, or for some other reason, they may suck the blood of others. *Pulex irritans*, besides being the natural parasite on man, apparently occurs naturally on badgers in Europe and on skunks in North America as well.

The economic importance of the family lies in the ability of the rat-flea, *Xenopsylla cheopis*, to transmit plague from rats to man and from man to man. For a long time there was much speculation as to the mechanism of infection. It was at length found that after the flea had taken in plague bacilli with the blood, a solid plug of culture of the germs gradually formed in the proventriculus. When next attempting to suck blood the flea, of course, was unable to do so, and its frantic efforts to appease its hunger forced a little of the culture

through the mouth and into the wound. According to Hall (1915) *Ct. canis* and *P. irritans* may also transmit plague.

Besides plague, Laveran and Nicolle (1913) regard as proven that both *P. irritans* and *Ctenocephalus serraticeps* transmit *Leishmania infantum*, the parasite of Kala-azar, to children and dogs in the Mediterranean region. The tapeworm *Dipylidium caninum* is carried by *Ct. canis*.

Echidnophaga gallinacea is another pest, the host being the domestic fowl. Known as the "sticktight" flea, it is more stationary in habit than those previously mentioned. The females, having once plunged their mouth-parts into the host, remain fixed in that position. The males are more restless and move about from time to time. Both sexes favour the head region. According to Illingworth (1916), the length of the life-cycle is three to four weeks. The same authority found that the imago might live from eight to thirty days without a host; on the other hand, if removed from a bird after a feed, it succumbed quickly. No eggs are laid until blood has been consumed.

Fleas are difficult to deal with; on animals a mineral oil emulsion is best or the powdered root of the Sweet Flag (*Acorus calamus*), which has a specific action on fleas (*fide* Liston). For clearing buildings, washing down with miscible mineral or tar oil is possible or fumigation with hydrocyanic acid gas.

Ceratopsyllidæ.

Head with a flap on each side of the frontal oral corner; often with a comb on the abdomen.

The species have been described by Rothschild and others, but there do not appear to be any records of their bionomics.

HYMENOPTERA

Two pairs of wings of almost equal size, hyaline and with few veins; mouth-parts always provided with mandibles, the maxillæ and labium usually formed into a lapping tongue. Metamorphosis complete.

The colour scheme in the *Hymenoptera* is very varied. Warning colours predominate in the *Aculeata*, such as wasps, hornets, bees, etc., the colours there being usually black combined with bands and spots of red or yellow.

Many harmless forms also exhibit these colours; *Sirex gigas*, a large insect conspicuously banded with yellow and black, is a good example. There are numbers of harmless saw-flies and Ichneumons which have a similar colour scheme. Aggressive mimicry is well developed in some forms: *Psithyrus rupestris*, a cuckoo-bee, bears an extraordinary resemblance to its host *Bombus lapidarius*, the colour and size of the two bees being almost identical.

On the other hand, the slender, wasp-like *Nomada ruficornis*—another cuckoo-bee which lives at the expense of *Andrena fulva*—bears not the slightest resemblance to its host, which is covered all over with a thick coat of orange-brown hairs.

Metallic colours are found in many of the *Chrysidæ*, *Vespoidea*, *Sphecoidea*, and *Chalcidoidea*. Cryptic colours are seldom to be seen, as few birds or insectivorous mammals care to attack *Hymenoptera*.

The size varies considerably; some of the *Mymaridæ* (*Chalcidoidea*) are among the smallest insects known, many being less than 1 mm long. The largest *Hymenoptera* seldom exceed two inches in length; this measurement, of course, excludes *Pelecinus*, which, though small, has an abnormally long abdomen, and also those Ichneumons which possess ovipositors some four inches long.

Hymenoptera are with few exceptions diurnal insects; *Ophion luteus* (*Ichneumonidæ*) often comes to light, as also do some winged ants. The hornet (*Vespa crabro*) remains active

after dusk and patronizes the Lepidopterist's " sugar " patches, much to the annoyance of collectors, and in the tropics *Xylocopa* works by moonlight. The *Hymenoptera* are distributed throughout the temperate and tropical regions of the world. In many cases the European fauna is greater than that of the tropics. Some *Tenthredinidæ* have been recorded from Spitzbergen, an island well within the Arctic circle.

The head is moderately large, free from the thorax and fairly mobile; the mandibles, which are always present, vary in shape, but are usually toothed; in many bees they are spatulate and form excellent organs for moulding wax, mud, etc. The maxillæ are sheath-like, consisting of a basal portion (stipes) and an apical outer lobe (galea); the inner lobe of the maxilla (lacinia) tends to become obsolete. The maxillary palp is usually well developed, being two- to six-jointed.

The labium is a somewhat complicated organ, though the essential parts can be readily traced; this organ reaches its highest development in the bees. There is a long hypopharynx, sometimes bilobed, flanked by the outer lobes of the labium (paraglossæ). On the outer side of the paraglossæ lie the labial palps, which are usually four-jointed; the inner lobes of the labium are frequently vestigial or absent.

Compound eyes and three ocelli are generally present in the adult *Hymenoptera*. The ocelli are absent in female *Mutillidæ*, and eyes are altogether wanting in some worker ants, the male *Blastophaga* (*Chalcidoidea*) and larvæ of *Petiolata*.

The antennæ are of moderate length and often elbowed, i.e. with a long basal joint (scape), the flagellum or remaining joints being each much shorter and proceeding at an angle to the scape. The antennæ are usually filiform, but the males of *Lophyrus* (*Tenthredinidæ*) have feathered antennæ not unlike those of male Saturniid moths. Some remarkable antennæ are to be found in the *Chalcidoidea*.

The wings, four in number, have no scales, though small hairs are frequently present; the number of nervures and cells varies enormously. In most of the *Hymenoptera* there is a small pigmented area on the costal margin termed the stigma. The hind-wings are connected to the fore-wings by a series of hooks which catch on to a fold in the inner

margin of the fore-wings. Not infrequently wings are absent or vestigial in one or both sexes.

The legs are of the normal running type, but a few remarkable modifications are to be found; the anterior tarsi in the *Dryinidæ* form a pincer in the female, and the basal tarsal joints of the posterior pair of legs in the *Apoidea* are expanded to form a pollen basket.

The trochanters are often divided in the *Serphoidea* and *Ichneumonoidea*.

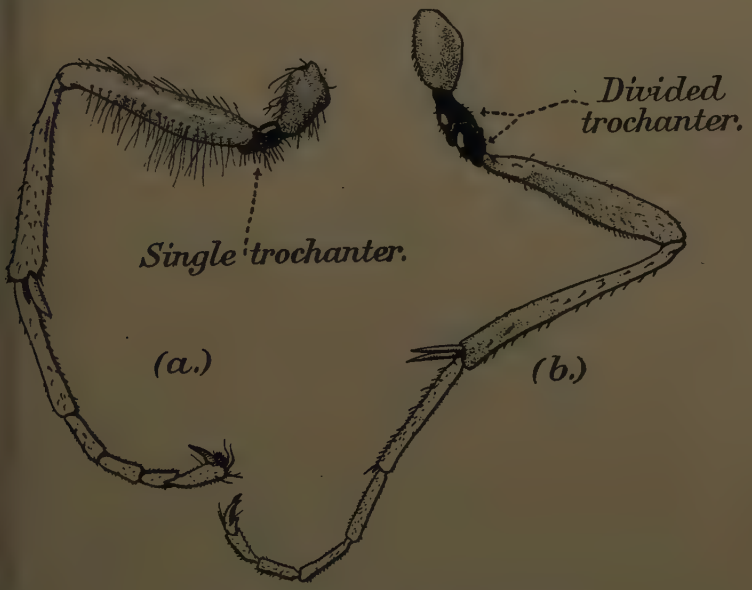


FIG. 161.—Single and Double Trochanters.
(*a.*) = leg of Vespid. (*b.*) = leg of Ichneumonid.

The thoracic segments are large and somewhat complicated; the prothorax frequently extends back to the tegulæ; this character is very important and is largely used in classification. The most remarkable feature in the thorax is the "median segment" or "propodeon"; this is really the first abdominal segment of the larva, but in the adult has become part of the thorax. The point of attachment of the first abdominal segment (really the second abdominal segment) to the median segment is used for classification purposes.

The abdomen is of various shapes and frequently very flexible. The number of segments varies, but in the *Aculeate* there are six in the female and seven in the male.

The males can always be distinguished from the females by the absence of the ovipositor; this organ may take the form of a saw, a sting, or a simple styliform ovipositor. The ovipositor is formed from the gonapophyses of the eighth abdominal segment and one gonapophysis of the ninth abdominal segment. The sting itself consists of two barbed darts which can slide up and down within a sheath; when the sting is employed both darts and sheath penetrate the skin,

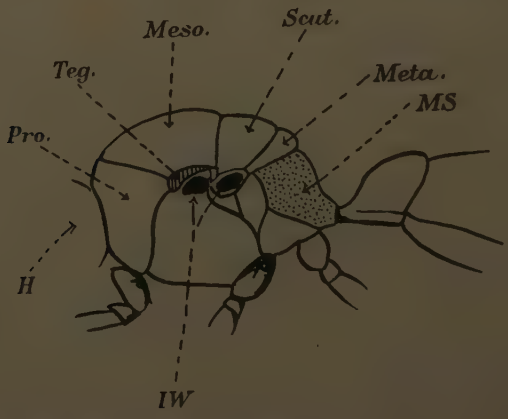


FIG. 162.—Diagram of Thorax of *Vespa* to show Median Segment.

Pro. = pronotum. *Meso.* = mesonotum. *Meta.* = metanotum. *Scut.* = scutellum. *MS.* = median segment. *Teg.* = tegula. *IW* = insertion of wings. *H* = head.

the former being driven deeper into the wound; at the same time poison from the poison sac runs down grooves in the darts and enters the wound.

In many bees the eyes of the male are very large and meet on the vertex, and in most of the *Aculeata* the antennæ of the female are twelve-jointed, those of the male being thirteen-jointed.

In the male the appendages of the ninth and tenth abdominal segments constitute what is known as the genital armature. This apparatus consists of two pairs of forceps, each attached to a basal portion; the outer pair are called the *stipites* (sing. stipes) and are attached to the *cardo*. The inner pair of

sagittæ are correspondingly attached to the *spatha*; in the *Vespidæ* and *Eumeniaæ* the sagittæ are generally united. The characters of the male genitalia are extensively used for the determination of species, especially among the Aculeates.

For further information see Saunders's article on the Terminal Segments of *Aculeate Hymenoptera*, *Trans. Ent. Soc. London* (1884).

The alimentary canal is of the normal type. The queens and workers of the social forms have the power of regurgitating honey, animal juices, etc., from the crop in order to feed their young. The nervous system is well developed, especially in wasps, bees, and ants. There are two large cephalic ganglia and two or three thoracic, the abdominal ganglia being two to seven in number. Tenthredinid larvæ have seven abdominal ganglia, and the larvæ of *Apoidea* have eight.

In the imago the hive-bee (*Apis*) has five abdominal ganglia in the worker, the queen and male having only four; *Bombus* workers and queens have six, the male five; *Vespa* workers have five, the males and queens six.

The tracheal system is normal; the position of the spiracles is sometimes used in the classification of the parasitic *Hymenoptera*. In many forms, especially *Apoidea*, there is an air bladder in the abdomen, the expanded main tracheal trunk.

Salivary glands are usually well developed; they are used by the larvæ for the production of silk for the cocoon, and by some adult forms (*Vespidæ*, etc.) for the secretion of a cement for strengthening the nesting materials. The spinnerets in the larvæ of *Tenthredinidæ* are situated in the labium.

In some *Apoidea*, wax is secreted on plates on the abdominal segments by unicellular glands; these glands reach their highest development in the hive-bee (*Apis mellifica*).

The reproductive system is complex; the number of egg-tubes in the female on each side varies considerably. Digger-wasps have only three egg-tubes, whereas *Apis* has about five hundred. Spermathecæ are present and are well developed in those insects which pair in the autumn and pass the winter in a state of inactivity.

A full account of the anatomy, both internal and external

of the hive-bee is contained in Cheshire's *Bees and Bee-keeping*, 2 vols.

The eggs are rather elongate on the whole, and in some cases are stalked. In the "digger wasps" and the *Eumenidæ* the stalk is short, the egg being suspended from the roof of the cell; in *Biorhiza aptera* (*Cynipidæ*) the stalk is long, though the purpose of the stalk in this case is somewhat obscure. The number of eggs laid by an individual female varies immensely. The "digger wasps" only lay about thirty eggs, while in the other extreme *Vespa* lays about 20,000 per annum.

Polyembryony, i.e. the production of several larvæ from one egg, is known to occur in one family of the *Chalcidoidea*. The form of the larvæ varies considerably. The larvæ of the *Tenthredinidæ*, which usually feed openly on plants, bear a great resemblance to Lepidopterous caterpillars in being cylindrical, thirteen-segmented and provided with three pairs of thoracic legs and a number of transitory pro-legs on the abdominal segments. The larvæ of the *Cephidæ* and *Siricidæ* are also free-living, but feed in the stems of plants or in solid timber where efficient organs of locomotion are not an essential factor for their development. In the *Petiolata*, however, the larvæ are vermiform and comparatively helpless, being dependent for food on a gall formation, the tissues of a host, or food brought or stored by the parent insects. These larvæ, though legless, have a distinct head and mouth-parts. When mature the larvæ in most cases spin a silken cocoon in which to pupate; many larvæ of *Cynipidæ* do not spin a cocoon, but pupate in the cavity of the gall. The pupæ are free, i.e. the legs, wings, and antennæ, though covered with the pupal skin, hang free from the rest of the body.

The food of both larvæ and adults is also extremely varied; the following table will show the food habits of some typical *Hymenoptera* in the larval and adult stages:

	Larva.	*Imago.*
Cephidæ	Stem-borer	Visits flowers
Tenthredinidæ	Leaves, fruit, etc.	Pollen, some carnivorous
Siricidæ	Wood	—
Cynipidæ	Galls—some parasitic	Visits flowers

	Larva.	*Imago.*
Chalcidoidea . .	Parasitic (some eat seeds)	—
Ichneumonidæ . .	,, . . .	Visits flowers.
Mutillidæ . .	,, . . .	,, ,,
Scoliidæ, *Sphecoidea*, *Pompilidæ*	Paralysed insects stored by parent . .	,, ,,
Vespidæ . .	Plant juice and insects	Same as larva.
Apoidea (some) .	Honey and pollen .	,, ,,
Formicidæ . .	Omnivorous . .	,, ,,

The *Tenthredinidæ*, *Cephidæ*, and *Siricidæ* hibernate as full-fed larvæ, though many *Siricidæ* take more than one year to complete their development. The *Cynipidæ* usually remain as larvæ in the galls, but one species, *Biorhiza aptera*, actually emerges in November. Most of the parasitic and aculeate *Hymenoptera* hibernate as adults; the female sex alone is often the survivor, the males dying off in autumn. Both sexes of *Andrena* (*Apoidea*) hibernate in the larval burrow; though they actually emerge from the pupa in autumn, the insects do not fly till April.

Very few birds will eat *Hymenoptera*, with the exception of the cuckoo, a bird which apparently delights in such unpalatable insects as Tenthredinid larvæ and hairy Lepidopterous caterpillars. The *Aculeata* are usually left alone for obvious reasons.

Many of the *Sessiliventres* are attacked by the hosts of parasitic *Hymenoptera*, which in turn suffer from hyperparasites.

Dalla Torre has catalogued the known species in *Catalogus Hymenopterorum*, 1892–1902. Most of the families have been monographed in *Genera Insectorum*, chiefly by Konow, Kieffer, Dalla Torre, and Szépligeti.

There are about 4,000 species recorded from Britain; Saunders has described the British *Aculeata* (*Trans. Ent. Soc. London*, 1880, 1882, 1884).

The *Hymenoptera* do not contain many serious pests; the *Sessiliventres*, Phytophagous *Chalcidoideæ* and some *Formicidæ* are the main groups on the black list. On the other hand, there are numerous beneficial insects; these are the Parasitic *Hymenoptera*, which destroy enormous numbers of caterpillars

and aphides, and the "digger wasps" and *Eumenidæ*, which catch various kinds of insects for their young.

The social wasps (*Vespidæ*) also destroy large numbers of caterpillars and flies, but are sometimes troublesome when they turn their attention to ripe fruit. A few tropical species of ants are useful in clearing houses of Termites, rats, and other vermin. Among the most useful of insects are the flower-visiting bees, as they probably pollinate more flowers than all the other flower-visiting insects put together.

Finally there is the hive-bee (*Apis mellifica*), which furnishes mankind with both honey and wax.

The classification of the *Hymenoptera* has been undergoing radical changes recently, ten super-families or groups having been formed. Under the old scheme of classification the *Petiolata* were divided into three groups, viz.: *Parasitica*, *Tubulifera* (*Chrysidæ* only), and *Aculeata*. The *Parasitica* was not a natural group; they were not all parasitic in habits, as they contained the *Cynipidæ* and of course the Phytophagous Chalcids. Moreover the structural characters of the *Parasitica* vary *inter se* to a considerable extent.

The old terms *Sessiliventres* and *Petiolata* will be retained here, as they form two very sharply defined divisions of the order.

The *Hymenoptera* may now be classified as follows:

A. SESSILIVENTRES.

No marked constriction at the base of the abdomen. Thorax and abdomen approximately equal in breadth.

Super-family or Group I. Tenthredinoidea.

Diagnosis as for *Sessiliventres*. Four Families—*Cephidæ*, *Siricidæ*, *Oryssidæ*, *Tenthredinidæ*.

B. PETIOLATA.

Deep constriction at base of first abdominal segment (apparently first abdominal segment) conspicuously separating the abdomen from the thorax.

II. *Cynipoidea.*

Body laterally compressed. Trochanters undivided; stigma absent, wings and tegulæ sometimes absent. One Family—*Cynipidæ*.

III. *Serphoidea.*

Small. Usually winged, but venation reduced. First abdominal segment not elbowed. Two Families—*Proctotrypidæ*, *Pelecinidæ*.

IV. *Chalcidoidea.*

Small insects; antennæ elbowed. Usually winged; wings with usually only one longitudinal nervure. Pronotum not reaching tegulæ; ovipositor not terminal. Frequently metallic. Twenty Families—(see p. 491).

V. *Ichneumonoidea.*

Trochanters usually divided. First abdominal segment elbowed. Cutting edge of mandibles turned outwards, their tips usually neither meeting nor overlapping when the mandibles are flexed towards the mouth. Five Families—*Ichneumonidæ*, *Braconidæ*, *Evaniidæ*, *Stephanidæ*, *Trigonolidæ*.

VI. *Chrysidoidea.*

Hairs simple, not branched or plumose. Abdomen with three segments visible from above; segments beyond third, hidden. One Family—*Chrysidæ*.

VII. *Vespoidea.*

Wings usually well developed. Hairs simple. Pronotum reaching tegulæ. Trochanters undivided. Cutting edge of mandibles turned inwards, their tips meeting or overlapping when mandibles are flexed towards the mouth. Ten Families—*Bethylidæ*, *Dryinidæ*, *Scoliidæ*, *Sapygidæ*, *Mutillidæ*, *Thynnidæ*, *Pompilidæ*, *Eumenidæ*, *Vespidæ*, *Masaridæ*.

VIII. *Sphecoidea.*

Pronotum not reaching tegulæ; posterior legs short. Fourteen Families—(see p. 513).

IX. *Apoidea.*

Dorsal hairs branched or plumose. Hind tarsi dilated. Seventeen Families—(see p. 516).

X. *Formicoidea.*

First abdominal segment (sometimes also the second) forming a knot or scale strongly differentiated from the remaining abdominal segments. One Family—*Formicidæ.*

Groups VII, VIII, IX, and X constitute the old division *Aculeata.*

Group I. *TENTHREDINOIDEA*

All the families in this group constitute the *Sessiliventres* and may at once be distinguished from all other *Hymenoptera* by the broad attachment of the abdomen to the thorax. Four

Fig. 163.—Larva of Tenthredinid (*Nematus ribesii*).

families will be dealt with in this work, though many sub-families have been raised to family rank; however, as these four families are very distinct, both in structure and habits, it will not be necessary to study their sub-families.

With one exception (*Orussidæ*) the members of this group are phytophagous in the larval state, and of considerable economic importance.

The *Tenthredinoidea* are widely distributed all over the world, but are more abundant in temperate regions than in the tropics.

Cephidæ.

Stem Saw-flies.

Prothorax long, free; fore tibiæ with one spine. Ovipositor short, external.

Cephidæ are widely distributed throughout the temperate regions; they have been found in North America, Mexico,

Japan, Britain, Sweden, and the Continent from Spain to Russia.

Stem saw-flies are rather slender, fragile insects, usually blackish, marked with yellow bands and spots. The wings are iridescent in the male and dull in the female. The antennæ are eighteen- to thirty-jointed, the first two joints being short and thick, the remainder slender, but gradually thickening towards the apex. The mouth-parts are rather weak; the labium is three-lobed and bears a four-jointed palp. The maxillary palpi are six-jointed.

The female deposits her eggs by means of her ovipositor in the stems of wheat, grass, etc. The egg hatches in about a week to an elongate footless maggot which at once commences to tunnel up and down inside the stem till mature, when it burrows down to the lowest part of the stem and spins a silken cocoon in which it passes the winter. The larva pupates in spring, the adult flies emerging in June, when they may be seen frequenting Umbelliferous flowers.

Besides grasses and wheat, *Cephidæ* have been bred from oak, willow, reeds, and brambles.

Ichneumons have been recorded as parasitizing *Cephidæ*, but not to cause any appreciable reduction in their numbers.

Cameron has dealt with the British species in his Monograph of the British Phytophagous *Hymenoptera*, published by the Ray Society in 1890. The *Cephidæ* have also been monographed by F. W. Konow in *Genera Insectorum*, Fasc. 27 (1905).

There are nine British species recorded, but only about two are common.

Stem saw-flies do considerable damage to wheat in America and on the Continent. The most destructive species are *Cephus pygmæus* in Europe and *Cephus occidentalis*—the "Western Grain Saw-fly"—in U.S.A. and Canada.

The damage is done by the larvæ tunnelling in the stems, with the result that the ears bear few grains. A slight wind is quite sufficient to break the stems of wheat when they are infested with larvæ.

The control measures usually adopted are:

1. Burning the stubble after the corn has been cut, so as to destroy the larvæ in the lowest part of the stalk.

2. Deep ploughing, to destroy the hibernating larvæ.

3. After harrowing, collecting the stubble in heaps and burning it.

Cephus pygmæus does not do much damage in Britain, but on the Continent it is regarded as a serious pest.

Siricidæ.

Wood-borers, Wood-wasps.

Ovipositor long. Anterior tibiæ with one spur; integument hard and strong.

Siricidæ are widely distributed, being found in Europe, North America, India, Malay Archipelago, and South America.

These insects are usually large and thick-set; they are black or metallic, sometimes banded and marked with yellow. The head is globular in shape; the antennæ are moderately long, filiform, and inserted between the eyes. The mandibles are strong and tridentate. The prothorax is well developed and the mesothorax has a transverse line in front of the scutellum. The females are provided with a strong projecting ovipositor.

The eggs of *Sirex* are laid in the wood of various coniferous trees, especially larch, pine, and spruce. The larvæ, which are cylindrical and yellowish-white in colour, bore galleries through the solid wood. When mature, they pupate at the end of a gallery close to the outer surface, so that the imago may readily force its way to the exterior of the tree.

Rhyssa persuasoria (*Ichneumonidæ*) is parasitic on the larvæ of *Sirex* in Britain. By some unknown means the parasite locates the burrow of its host in the wood and thrusts its slender ovipositor through the solid timber.

The *Siricidæ* have been monographed by F. W. Konow in *Genera Insectorum*, Fasc. 28 (1905), and the British species by Cameron (see *Cephidæ*).

There are four British species—*Sirex gigas*, *S. juvencus*, and two species of *Xiphydria*. Several Continental and American species have been recorded in Britain, but have probably been imported in timber and furniture.

It may be mentioned here that *Xiphydria* and allied genera

have been placed in a separate family—*Xiphydriidæ*. Here, however, they are retained in *Siricidæ*.

Sirex is not sufficiently common in Britain to cause any serious damage, but on the Continent the damage to the pine forests is very serious. It is, moreover, a very difficult pest to control. Fallen trees should be removed and burnt, as they are often infested with larvæ. The exit holes made by the insects will afford a ready means of determining whether a tree is attacked or not.

Oryssidæ.

Antennæ placed below level of the eyes and immediately over the mandibles. Anterior tarsi three-jointed in the female and five-jointed in the male. Front tibiæ with one spur; mandibles without teeth; female with ovipositor.

At present very little is known of the habits of *Oryssidæ*, but it has been proved that *Oryssus occidentalis* is parasitic on the larvæ of wood-boring *Buprestidæ*.

Oryssus abietinus is the only species which is found in England, but it is very rare.

The family has been monographed in *Genera Insectorum*, Fasc. 28, by F. W. Konow; evidence of the parasitic habits of *Oryssus* appeared in the *Proceedings of the Entomological Society of Washington*, vol. XIX (1917), by Burke and Rohwer.

Tenthredinidæ.

Saw-flies.

Pronotum small. Anterior tibiæ with two spurs. Female provided with a saw.

This is a widely distributed group, being found in nearly every quarter of the globe, but they are more commonly found in the northern temperate regions than in the tropics. Several species have been recorded from Iceland and Spitzbergen.

Saw-flies are moderate-sized insects, rather heavily built. The abdomen is broadly attached to the thorax. The antennæ

are three- to forty-jointed. The ovipositor of the female takes the form of a saw, and is usually concealed. The mandibles are short and thick; the maxillæ have two lobes and a six-jointed palp; the labial palps are four-jointed. The wings are frequently iridescent or smoky; in one species the female is apterous.

Fig. 164.—*Tenthredinidæ*—Saws of a Saw-fly.

The eggs are laid in the tissues of the food-plant either in the leaf or in the petiole. The larvæ hatch out and rapidly devour the leaves. Some species make galls, notably *Nematus gallicola* on willow leaves, others are leaf-miners, but the majority of saw-fly larvæ feed openly on the leaves after the

Fig. 165.—*Tenthredo mesomelus.* (× 3.)

manner of Lepidopterous larvæ. Saw-fly larvæ differ from Lepidopterous caterpillars by possessing six to eight pairs of pro-legs, whereas caterpillars never have more than five

pairs. When mature, the larvæ usually burrow into the soil and spin silken cocoons in which they pupate. There are frequently two broods produced in the year, but the winter is always passed in the larval stage in the cocoon and not as pupæ. The adult flies appear in June, and where there is a second brood, in July and August. Many species are pollen-feeders, but others are carnivorous, especially those belonging to the genus *Tenthredo*. Parthenogenesis often occurs, males or females, or more rarely both sexes, being produced from unfertilized eggs.

The larvæ of *Tenthredinidæ* are frequently parasitized by *Tachinidæ*, *Ichneumonidæ*, and *Chalcidæ*. Many species are distasteful to birds, but cuckoos have been observed to feed on the larvæ of *Nematus ribesii*. This species is also attacked by wasps (*Vespa*).

Fig. 166.—Head of *Lophyrus Rufus* ♂.

The *Tenthredinidæ* have been monographed in *Genera Insectorum*, Fasc. 29 (1905), by F. W. Konow, and the British species have been described by Cameron.

There are about 2,000 species known, of which nearly 400 are found in Britain.

The economic importance of the *Tenthredinidæ* is considerable; the larvæ do much damage by defoliating trees and crops, while a few species attack apples, pears, and plums: *Hoplocampa testudinea*, the "Apple-fruit Saw-fly," is a notable example of the latter class.

Among the leaf-eaters the cosmopolitan turnip saw-fly, *Athalia spinarum*, and the currant saw-fly, *Nematus ribesii*, are worthy of mention. *Lophyrus pini* and *Nematus erichsoni* often cause serious damage to pine and larch plantations respectively.

The measures adopted for control necessarily vary according to the species in question and the prevalence of the pest.

In small gardens and orchards the larvæ may be hand-picked: this is an efficient method, as the larvæ are easily seen and are often markedly gregarious.

By turning over the soil under the trees in winter, many of the hibernating larvæ are exposed and either die from exposure or are eaten by birds. An alternative method is to dig the cocoons deeper into the soil, so as to prevent the perfect insects emerging in spring: these cultural methods are perhaps the most satisfactory, though arsenical sprays have been used with some success.

Group II. *CYNIPOIDEA*

Body laterally compressed; trochanters undivided; stigma absent; wings and tegulæ sometimes absent.

Three families have been recognized, but the classification adopted by Kieffer and Dalla Torre in *Genera Insectorum* will be adopted here, viz.: One family, *Cynipidæ*, with eight sub-families.

Cynipidæ.

Gall-wasps.

Small to minute insects, seldom exceeding 5 mm. in length; the fore-wing with no stigma and not more than five closed cells; hind-wing with two or three nervures. Antennæ straight with less than sixteen joints. The pronotum reaches the insertion of the fore-wings.

Cynipidæ are widely distributed throughout the world but are more in evidence in the northern temperate zones, especially where the oak is to be found.

The antennæ are not elbowed and are always less than sixteen-jointed; the male usually has one, sometimes two joints more than the female. The wings are rather sparsely veined and never have a stigma; the margin of the wing may be fringed with hairs and sometimes the surface is hairy.

The mandibles are short and strong, and usually toothed. The labium is entire and truncated. The maxillæ have an outer lobe and a four- to five-jointed palp, but the inner lobe is absent. The trochanters are not divided.

The females lay their stalked eggs in the cambium tissues of plants. In due course the larva hatches out, and the formation of the gall commences. The larvæ are fleshy, whitish in colour, and have no legs. The mature larvæ do not spin cocoons, but pupate within the gall, and the perfect insect finally bores its way out of the gall. So far as is known the adults do not feed much, nor do they fly very far. When alarmed many species feign death in order to escape their enemies. The galls are to be found on many kinds of vegetation, though the majority are to be found on the oak. Closely allied species of *Rhodites* are remarkable for the widely divergent types of galls that they make on rose trees.

There are several species of *Cynipidæ* in which the male is unknown, the parthenogenetic female alone being represented. An alternation of generations is fairly common; the case of *Biorhiza aptera* and *Andricus terminalis* may be quoted. The former, which occurs in autumn, is rather large and wingless, and of the female sex only; these lay their eggs in the buds of oak and produce the well-known "oak-apple" which gives rise to the bisexual *Andricus terminalis* in June. Another interesting case is that of *Rhodites rosæ*, which forms the common "bedeguar" galls on roses. The male is exceedingly rare in comparison with the females, which have been proved to be parthenogenetic.

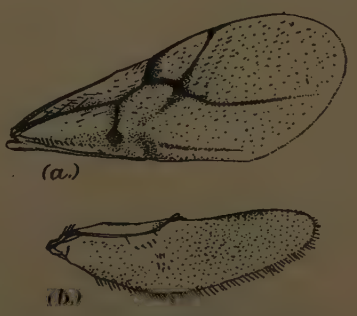


FIG. 167.—*Cynipoidea*. Wing of *Psilodora boienii*.
(*a.*) = fore-wing. (*b.*) = hind-wing.

There are three main classes of *Cynipidæ*:

1. The true gall-makers.
2. The inquilines or "guests," which lay their eggs in the galls of other species.
3. Parasites—chiefly attacking *Aphides*, *Diptera*, *Coleoptera*,

Sirex, *Hemerobius*, and also found as hyper-parasites on *Aphides*.

The *Cynipidæ* have been divided into eight sub-families, of which the most important are the *Figitinæ*, the *Ibaliinæ*, and the *Cynipinæ*. These sub-families are all based on structural characters, but in a general way it may be said that the *Figitinæ* and the *Ibaliinæ* are parasitic and that the *Cynipinæ* comprise the gall-makers and inquilines.

The *Cynipidæ* are parasitized to a great extent by *Chalcidoidea*. The gall-makers are kept in check by the hosts of inquiline *Cynipidæ*; sometimes the inquiline and the original gall-insect both reach maturity, but usually the inquiline causes the death of the legitimate tenant.

There are about 180 British species recorded; the majority of the *Cynipinæ* are to be found on oak trees throughout the country. The *Cynipidæ* have been monographed in *Genera Insectorum* by J. J. Kieffer and K. W. von Dalla Torre, Fasc. 9 and 10 (1902–1903). The British species are described by Cameron in *British Phytophagous Hymenoptera*, vols. III and IV.

Cynipidæ are not of great economic importance, except in so far as the formation of large numbers of galls interferes with the growth and health of the host plant.

Cynips kollari, "the Marble Gall," when numerous, is apt to stunt and distort the young oaks.

Diastrophus turgidus in America forms galls on the roots of the raspberry and bramble, and *Cynips olecæ* is recorded as a pest on olive in Italy.

Group III. *SERPHOIDEA*

Small. Usually winged, but venation reduced. First abdominal segment not elbowed.

Formerly this group was termed "*Oxyura*" and comprised the family *Proctotrypidæ*. According to the latest classification, the *Proctotrypidæ* have been split into seven new families, and placed along with the *Pelecinidæ*, to form the *Serphoidea*. The old family name of *Proctotrypidæ* will be retained here as a whole, and the *Pelecinidæ* will be dealt with separately.

Proctotrypidæ.

Small insects with few or no nervures in the wings. Prothorax reaching back to the tegulæ. Ovipositor terminal.

These insects are widely distributed in Europe and North America, where they have been studied to some extent. As yet little is known of the habits and distribution of the group in Africa and Australia and Oriental Asia.

The antennæ are seven- to fifteen-jointed and may be either straight or elbowed. The mandibles are usually toothed and the maxillæ are bilobed and bear a two- to six-jointed palp.

The venation of the wings varies considerably, the stigma being usually well defined, but some species possess no stigma and hardly any nervures; not infrequently the wings are absent in one or both sexes.

The trochanters may be divided or undivided. The abdomen is pointed, and often deflexed at the tip. In the female, the ovipositor issues from the tip of the abdomen; this character serves to distinguish them from the *Chalcidoidea*.

So far as is known the *Proctotrypidæ* are all parasitic in the eggs or bodies of insects and spiders. Pupation takes place in the egg-shell of their host, or within the dead body of their victim. In the case of those species which infest the larvæ of *Coleoptera*, the parasites gnaw their way out a certain distance before pupating.

There are several British species recorded.

The *Proctotrypidæ* of North America have been monographed by Ashmead (1893). J. J. Kieffer has listed most of the families in *Genera Insectorum*:—*Ceraphronidæ*, Fasc. 94; *Serphidæ*, Fasc. 95; *Belytidæ*, Fasc. 107 (1910); *Diapriidæ*, Fasc. 124 (1911); *Scelionidæ*, Fasc. 80 (1908) by C. T. Brues, with additional notes by Kieffer (1910).

The *Proctotrypidæ* are very beneficial insects, as they are parasitic on the most destructive of insects. *Platygaster herrickii* is a parasite of the Hessian fly (*Cecidomyia destructor*). The following list of families and their hosts will serve to show how beneficial these parasites are in reducing the numbers of pests.

Platygastridæ.

Parasitic on the larvæ of *Cecidomyiidæ* and *Tipulidæ*; also recorded as a hyper-parasite on a *Cecidomyiid* which was parasitic on *aphides*. This family also attacks *Aleurodidæ*.

Scelionidæ.

These are all egg parasites. One genus has been recorded as parasitizing the eggs of aquatic insects. Species have been bred from the eggs of the following insects:—*Bombycidæ Noctuidæ*, *Arctiidæ*, *Geometridæ*, *Pentatomidæ*, *Aradidæ*, *Coreidæ*, *Pyrrhocoridæ*, *Carabidæ*, *Gryllidæ*, *Acridiidæ*, and spiders.

Ceraphronidæ.

Parasitic on the larvæ of *Cecidomyiidæ* and *Aphidæ*.

Heloridæ.

Bred from the cocoons of *Chrysopidæ*.

Diapriidæ.

Parasitic on larvæ of *Diptera*.

Belytidæ.

Parasitic on larvæ of *Diptera*.

Serphidæ.

Bred from larvæ of *Coleoptera* and *Diptera* living in fungi

Pelecinidæ.

Female with a very long abdomen. Trochanters not divided.

Little seems to be known of the habits and distribution of this family, but one species, *Pelecinus polyturator*, is quite common in America, where it is parasitic on the larvæ of cockchafers.

The female can be at once recognized by the extraordinary length of the abdomen, which may be two inches long or more; the male, however, is of normal proportions.

Group IV. *CHALCIDOIDEA*

Small insects ; antennæ elbowed ; usually winged ; wings with usually only one longitudinal nervure. Pronotum not reaching tegulæ. Ovipositor not terminal. Frequently metallic.

This is a very extensive group of *Hymenoptera*, thousands of species being recorded from all parts of the world.

They were previously all relegated to the family *Chalcidæ* (*Chalcididæ*), but now they are separated into twenty families. They are chiefly parasitic and their habits are all more or less similar, but special reference will be given to those species which are phytophagous.

The families are all based on small structural characters, hence it will not be necessary to mention them except those likely to come before the notice of the Economic Entomologist.

The *Chalcidoidea* may be classified into the following families.—*Mymaridæ*, *Trichogrammidæ*, *Tetrastichidæ*, *Entedontidæ*, *Eulophidæ*, *Elasmidæ*, *Elachertidæ*, *Pteromalidæ*, *Spalangidæ*, *Tridymidæ*, *Aphelinidæ*, *Encyrtidæ*, *Signiphoridæ*, *Eupelmidæ*, *Callimomidæ*, *Eurytomidæ*, *Perilampidæ*, *Eucharidæ*, *Chalcididæ*, *Leucospidæ*.

Chalcids are small insects, frequently minute, with the exception of *Leucospis gigas*—and often of bright metallic colours.

The antennæ are seven- to thirteen-jointed and elbowed. The fore-wings usually have one vein proceeding from the base and running parallel with the front margin, then, uniting with the costa, it gives off a short and rather thick branch towards the middle of the wing. This small branch is sometimes forked or clubbed.

Apterous forms are to be met with in both sexes.

The parasitic forms attack the eggs, larvæ, and pupæ of other insects, and in the case of *Aphidæ* and *Coccidæ* the adults are parasitized. No insects appear to be free from their attacks, gallicolous *Cynipidæ*, *Lepidoptera* in all the early stages, and *Diptera* are most frequently parasitized. Hyper-parasitism

sometimes occurs: *Pachycrepis* sp. is parasitic on a *Braconid* which attacks Aphids.

The most interesting of the parasitic forms are the *Mymaridæ*. These insects, which were previously classed with the *Proctotrypidæ*, are very small indeed and are parasitic on the eggs of other insects. The wings are very narrow and fringed with long hairs. Some of these minute Chalcids pass their early stages in the eggs of dragon-flies and possess the faculty of swimming under water. In the family *Eurytomidæ* are to be

FIG. 168.—*Nasonia brevicornis*, a pupal parasite of the Blow-fly (greatly enlarged).

found several Phytophagous species, which are regarded as pests in America. The most important of these are *Isosoma tritici*, the "Wheat-joint Worm"; *Isosoma hordei*, which attacks barley; *Bruchophagus funebris*, which feeds as a larva in clover and lucerne seeds; and *Euoxysoma vitis*, which feeds in grape seeds.

Megastigmus spermotrophus lays its eggs in the seeds of Douglas fir, and has lately been causing considerable damage in this country.

About 4,000 species of Chalcids have been described, of

which 1,400 are British. No doubt many more will be discovered.

The *Chalcidoidea* have been monographed in *Genera Insectorum*, Fasc. 97 (1909), by O. Schmiedeknecht. Claude Morley has catalogued the British species, *Brit. Mus. Nat. Hist.* (1910).

The economic importance of the group is considerable. The parasitic forms are very beneficial in reducing the numbers of caterpillars and flies. On the other hand the Phytophagous species are very injurious to their food-plants.

Isosoma (*Harmolita*) *tritici* forms galls at or near the joints in wheat stems; the larvæ feed within the gall, and when mature hibernate therein and pupate in spring.

The fig-insect, *Blastophaga grossorum*, is a very interesting Chalcid, which is considered to be an essential factor in the development of the fig. The male is apterous, but the female has well-developed wings. It appears that the fig-insects breed only in the wild figs and that the males do not leave the fruit but fertilize the females, which fly away to deposit their eggs on other figs. The cultivated fig, however, seems to be unsuitable for the development of the insect, but as the female wanders about the young figs, they are fertilized by the pollen which the *Blastophaga* has carried from the wild fig. For this purpose, branches of wild figs containing *Blastophaga* are hung up in the orchards of cultivated figs, so that the process of "caprification," as it is termed, may be accomplished.

Group V. *ICHNEUMONOIDEA*

Trochanters usually divided. First abdominal segment elbowed. Cutting edge of mandibles turned outwards, their tips usually neither meeting nor overlapping when the mandibles are flexed towards the mouth.

This is another large group of insects, consisting of an enormous number of species. The constriction between the abdomen and the thorax is very strongly marked and the trochanters are nearly always divided.

There are five well-defined families, viz. *Ichneumonidæ*, *Braconidæ*, *Evaniidæ*, *Stephanidæ*, *Trigonalidæ*.

The last two families are apparently rare and little is know of their habits. Four other families have been placed in thi group: *Vipionidæ*, *Alysiidæ*, and *Capitonidæ* are placed b Szépligeti in *Genera Insectorum* along with the *Braconidæ*, an the *Banchidæ* are included in the *Ichneumonidæ* (Morley).

Ichneumonidæ (including *Banchidæ*).

"Ichneumon-flies."

Trochanters divided. Antennæ not elbowed. Wings wit a well-developed system of venation.

The *Ichneumonidæ* comprise some 6,000 species from al parts of the world.

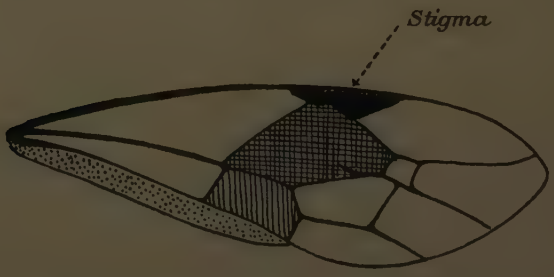


Fig. 169.—*Ichneumonidæ*. Diagram of Fore-wing.
(The three cells across the wing are each shaded differently.)

They appear to be as common in the temperate regions a in the tropics.

The size varies greatly. They are often black, conspicuousl marked with yellow or red spots and bands. Species of th genus *Ophion* are usually bright red in colour with no marking

Apart from structural characters, Ichneumons can generall be recognized in the field by their short, jerky flight an constantly vibrating antennæ.

The antennæ are rather long, usually filiform, and many jointed. The pronotum is short, but extends laterally to th insertion of the fore-wings. The legs are long and the divisio of the trochanters is well marked. The female usually ha the ovipositor projecting beyond the extremity of the bod

The ovipositor is sometimes much longer than the body of the insect.

The wings are usually well developed, though apterous forms are not uncommon. *Pezomachus* is a common British wingless Ichneumon.

Ichneumons are all parasites and usually select Lepidopterous caterpillars and saw-fly larvæ as their victims, though many other insects and spiders are attacked. The egg is laid either on the skin or in the body of the host, and a legless larva hatches out.

Rhyssa persuasoria, a large Ichneumon which is found in Britain, selects the larvæ of *Sirex* for its host. The long ovipositor is thrust into the wood and an egg is laid in the burrow of the *Sirex* larva; the young Ichneumon larva on hatching seeks out the *Sirex* larva and feeds on it as an external parasite.

Most Ichneumon larvæ, however, are internal parasites, living inside the host and feeding on the lymph, the vital organs not being touched, as this would result in the premature death of the host and the subsequent starvation of the parasite.

The host usually attains full growth before death, by which time the parasite is also mature.

Pupation usually takes place in a silken cocoon, often inside the cocoon of the host.

The general life-history of the *Ichneumonidæ* is fairly uniform, though mention should be made here of *Agriotypus armatus*—a species which has the faculty of going under water for the purpose of laying its eggs in the larvæ of Caddis-flies.

There are over 1,200 species recorded from Britain. These have been treated by Claude Morley in *British Ichneumons*.

The following is a list of references in *Genera Insectorum* :—

Fasc. 18 (1904) sub-fam. *Ichneumoninæ*, by V. Berthoumieu.
,, 34 (1905) ,, *Ophionidæ*, *Pharsaliinæ*, etc., by G. V. Szépligeti.
,, 62 (1907) ,, *Pimplinæ*, by O. Schmiedeknecht.
,, 75 (1908) ,, *Cryptinæ*, by O. Schmiedeknecht.
,, 114 (1911) ,, *Ophionidæ*, etc., by G. V. Szépligeti.

The family has been catalogued by Morley in *Revision of the Ichneumonidæ*, *Brit. Mus. Nat. Hist.* (1912).

The economic importance of the *Ichneumonidæ* is enormous As they are chiefly parasitic on *Lepidoptera*, they materiall check the numbers of caterpillars which infest nearly ever crop.

Some Ichneumons are troublesome when they confine thei attentions to silk-worms and collectors do not welcome thei presence when rearing rare butterflies and moths. These tw cases must be ignored, however, in view of the enormou amount of good that they do in destroying caterpillars tha are injurious to crops.

BRACONIDÆ (including *Vipionidæ*, *Alysiidæ*, and *Capitonidæ*)

Antennæ long, not elbowed. Abdomen not inserted o apex of median segment. Fore-wings with four cells acros the wing from the stigma to the inner margin, and the spac between the cubital cells and the anal cell not divided by nervure.

This is a very large family and appears to be widely di tributed all over the world.

Braconids are rather similar to Ichneumons at first sigh

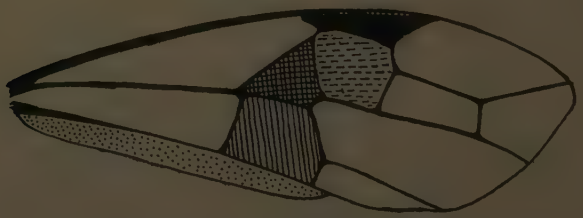


FIG. 170.—*Braconidæ*. Diagram of Fore-wing.
(The four cells across the wing are each shaded differently.)

but can be readily distinguished by comparing the venatio of the fore-wings. As a rule, the Braconids are smaller an duller than Ichneumons, but some of the tropical forms a large and brightly coloured. The wings are often banded blotched.

Most of the *Braconidæ* are winged, but in a few rare cas the female, or even both sexes, are apterous. The head rather large, with long antennæ. The abdomen varies

shape considerably and in the female there is usually a long ovipositor.

The life-history of the *Braconidæ* is very similar to that of the *Ichneumonidæ*.

They are all parasitic, and most of them live inside the body of the host, usually Lepidopterous larvæ, though Dipterous larvæ, aphids, and ants are also parasitized.

Fig. 171.—*Alysia manducator*. (× 6.)

The smaller forms such as *Microgaster* and *Apanteles* are to be found in large numbers within the body of a single host: sometimes over 1,000 parasites have been bred from one caterpillar.

The larvæ when mature spin masses of yellow or white cocoons on or near the body of the victim.

The *Braconidæ* have been monographed by G. V. Szépligeti in *Genera Insectorum*, Fasc. 22 (1904). Marshall has described the

British species in the *Transactions of the Entomological Societ of London*, commencing in 1885.

Further information about the British *Braconidæ* appeare in the *Entomologist*, 1920–1921, by Lyle.

The *Braconidæ* are of great value to the agriculturist *Apanteles* and *Microgaster* appreciably reduce the numbe of caterpillars in this country, and *Rhogas lefroyi* is a ver important check on the spotted bollworms, *Earias insulan* and *E. fabia*, in India.

Evaniidæ.

The petiole of the abdomen is attached to the upper par of the median segment. Antennæ filiform, thirteen- t fourteen-jointed.

The *Evaniidæ* are widely distributed throughout th temperate and tropical regions.

Fœnus (*Gasteruption*) *jaculator* is a common British species

Fig. 172.—*Evaniidæ*. Thorax of *Fœnus*, showing Insertion of Abdomen.

The pronotum is rather short. The posterior legs are rathe long, the tibiæ being frequently clubbed at the distal end The trochanters are divided, though very imperfectly, th distal portion being very small and hardly to be distinguishe from the longer proximal joint.

The *Evaniidæ* are all parasitic in habits. The species o the genus *Evania* lay their eggs in the egg capsules of *Blattida* and *Aulacus* lives at the expense of *Siricidæ* (*Xiphydri*

and a few species of *Cerambycidæ*. *Fœnus* (*Gasteruption*) is parasitic on *Apidæ*, *Vespidæ*, and *Sphecoidea*, and may be seen in this country searching wooden posts, fences, etc., for the nests of their hosts.

A monograph of the *Evaniidæ* appeared in *Genera Insectorum*, Fasc. 2 (1902), by J. J. Kieffer.

Stephanidæ.

Antennæ many-jointed. Abdomen attached to lower part of the median segment. Wings with a costal cellule. Trochanters divided.

There are only about 100 species of *Stephanidæ* known from various parts of the world. They occur in the tropics and have been found in France and Germany.

There are no British species.

The head is globose, and the antennæ are very long, being composed of thirty to seventy joints. The maxillary palps are also rather long, and five-jointed. The wing venation is varied; the stigma is generally well defined and there are from three to eight cells in the fore-wings. The abdomen is attached to the lower portion of the median segment. The female has a long ovipositor.

Nothing appears to be known of the life-history and habits of this family.

J. J. Kieffer has monographed the *Stephanidæ* in *Genera Insectorum*, Fasc. 77 (1908).

Trigonalidæ.

Trochanters imperfectly divided. Abdomen consisting apparently of only five segments. Venation well developed in both pairs of wings.

The *Trigonalidæ* are found chiefly in South and Central America, though they have been recorded from Africa, Australia, Burma, Canada, U.S.A., and Europe. One species, which is very rare, has been recorded from Britain.

These insects bear a great resemblance to some of the fossorial wasps and parasitic bees of the genus *Nomada*. They

are usually blackish in colour, marked and banded with red or yellow. The head is large and broad, and the antennæ are twenty-five-jointed. The trochanters are divided, but the division is not nearly so well marked as in the *Ichneumonidæ*. The wings have a well-developed system of venation, somewhat similar to that found in the fossorial wasps.

The life-history appears to be very imperfectly known. It has been ascertained, however, that they are parasitic on other *Hymenoptera*, especially the social wasps belonging to the genera *Vespa* and *Polistes*.

The *Trigonalidæ* are also known to be hyper-parasites on *Diptera* (*Tachinidæ*).

W. A. Schultz has monographed the family in *Genera Insectorum*, Fasc. 61 (1907).

Group VI. *CHRYSIDOIDEA* (*Tubulifera*)

This group consists of but one family—*Chrysidæ*.

Chrysidæ (*Chrysididæ*).

Ruby-wasps.

Trochanters undivided. Abdomen of three visible segments when viewed from above. Female with retractile ovipositor.

The *Chrysidæ* are distributed all over the world, though the family is not very large.

These insects may be easily recognized in the field; they are usually to be seen in the hot sunshine flying about old walls and fences. Their brilliant metallic colours, restless habits and constantly vibrating antennæ are characteristic of the family. The antennæ are rather short and strongly elbowed. The wings are comparatively small and usually smoky. The stigma is somewhat reduced. The integument is very hard and usually thickly punctured. Chrysids have the remarkable power of curling themselves into a ball, in which position they are more or less protected from the stings and jaws of their enemies. The ovipositor of the female is enclosed in a segmented, retractile sheath.

The *Chrysidæ* are parasitic on Aculeate *Hymenoptera*, especially *Eumenidæ*.

Chrysis shanghaiensis and *C. bombycida*, however, live at the expense of *Lepidoptera*.

The egg is laid in the provisioned cell of the wasp and hatches to a fat, legless larva. Generally the Chrysid larva feeds on the developing wasp larva, though a case has been recorded where the *Chrysis* larva fed on the caterpillars which had been stored by the mother wasp for the benefit of her young.

Fig. 173.—*Stilbum cyanurum* (F. M. Howlett).

When fully grown the larva spins a cocoon and pupates in spring in the cell of the host, the perfect insect emerging shortly afterwards.

There is a monograph of the *Chrysidæ* by H. Bischoff in *Genera Insectorum*, Fasc. 151 (1913).

There are about twenty-four species recorded from Britain.

Chrysis ignita is the commonest species; it may be seen searching walls and fences for the nests of *Odynerus* (*Eumenidæ*) in May and June.

These insects are of no economic importance.

Group VII. *VESPOIDEA*

Wings usually well developed. Hairs simple. Pronotum reaching tegulæ. Trochanters undivided. Cutting edge of mandibles turned inwards, their tips meeting or overlapping when mandibles are flexed towards the mouth.

The *Vespoidea* and the succeeding groups belong to the *Aculeata* or stinging *Hymenoptera*. The *Vespoidea* may be distinguished from the *Sphecoidea*, which they closely resemble,

by the pronotum reaching back to the tegulæ, and from the *Apoidea* and *Formicoidea* by the absence of branched or plumose hairs and the absence of abdominal nodes respectively.

The old division "*Diploptera*," comprising the *Vespidæ* and

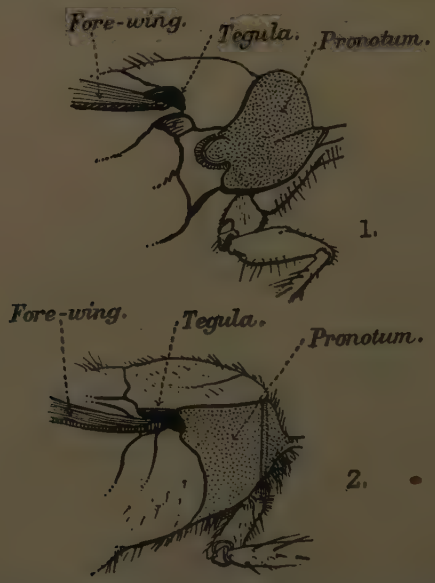


FIG. 174.—1. Thorax of *Sphecoidea* (Pronotum not reaching Tegula).
2. Thorax of *Vespoidea* (Pronotum reaching Tegula).

Eumenidæ, is abolished, these two families being now placed in this group. The *Bethylidæ* and *Dryinidæ*, which were originally in the "*Parasitica*," are also relegated to the *Vespoidea*.

There are ten well-defined families.

BETHYLIDÆ.

Antennæ usually thirteen-jointed. Wings frequently absent in the female. Hind-wings with a lobe.

This is a small family, but widely distributed.

The *Bethylidæ* were placed by Ashmead with the *Proctotrypidæ* in his monograph of those insects; they are now, however, placed in the Aculeates.

The prothorax is long and the median segment is well developed. The wings are often reduced or absent in the female, and sometimes in the male. The venation varies considerably: in some forms the cells are well marked and in others there may be only two small veins not extending more than one-fourth of the length of the fore-wing. The hind-wings usually have no veins at all, except a subcostal, and the lower margin near the base is frequently lobed. The abdomen is of seven to eight segments, and the petiole is very short.

The *Bethylidæ*, so far as is known, are all parasitic in habits.

They have been bred from various Lepidopterous and Coleopterous larvæ: some species attack the larvæ of wood-boring beetles, and others have been found in ants' nests, where they are probably parasitic on the larvæ of myrmecophilous insects.

J. J. Kieffer has monographed the *Bethylidæ* in *Genera Insectorum*, Fasc. 76 (1908).

They are of no economic importance.

Dryinidæ.

Female with the fore-leg modified to form a pincer.

The *Dryinidæ* are found chiefly in Europe, North America, and Australia. A few species have been recorded from Asia and Africa.

The antennæ are ten-jointed, usually filiform, and not infrequently clubbed. The wings are often pigmented and sometimes reduced or altogether absent. The hind-wings often have a lobe. With the exception of the genus *Aphelopus* the fifth joint of the tarsus is modified in the female to form a pincer. The trochanters are not divided. The abdomen consists of eight segments, the petiole being very short. The ovipositor of the female is not external.

The *Dryinidæ* are all parasitic in habits; a few species have been found in ants' nests, but their life-history is not clear, most live at the expense of the Homopterous families *Fulgoridæ* and *Jassidæ*. The female holds the Homopterous nymph with its pincers and proceeds to deposit its eggs in the

body of the host. When the larvæ are mature they pupate in a white cocoon fixed to the food-plant of the host.

The family has been monographed by J. J. Kieffer in *Genera Insectorum*, Fasc. 54 (1907).

About 300 species are known.

The *Dryinidæ* furnish a good example of the value of imported parasites; a sugar-cane leaf-hopper (*Perkinsiella saccharicida*—family *Fulgoridæ*) was accidentally introduced from Australia to Hawaii, where it became a pest.

Parasites, including several species of *Dryinidæ*, were exported from Australia and were instrumental in appreciably reducing the numbers of the Fulgorid in Hawaii.

Two species of *Dryinidæ* are recorded as parasites on the sugar-cane leaf-hopper (*Pyrilla aberrans*—*Fulgoridæ*) in India. Ref., *Memoirs Dept. Agr. India*, Vol. V, No. 11 (1917), C. S. Misra.

Scoliidæ.

Digger-wasps.

A constriction between first and second abdominal segments. Middle coxæ separated; middle tibiæ with one spur. Both sexes winged. Pronotum reaching tegulæ.

Widely distributed throughout the tropics, the *Scoliidæ* appear to be rather scarce in the temperate regions. Only two species, *Tiphia femorata* and *T. minuta*, are found in Britain.

The *Scoliidæ* may be recognized in the field by their large size, stout legs, and rather thick-set, hairy bodies. They are usually blackish in colour with yellow or red spots and bands. The head is large and bears strong mandibles; the antennæ are rather short in the female, longer and more slender in the male. The venation of the wings is well developed, but the nervures do not reach the outer margin. The female is generally much larger, and is of course provided with a sting.

Scoliidæ live at the expense of Coleopterous larvæ, chiefly *Melolonthidæ*. The female searches for a cockchafer larva, usually in the ground or in decaying vegetable matter, and paralyses it by stinging it in some particular nerve ganglion.

An egg is then laid on the unfortunate larva and the mother wasp flies away to repeat the performance elsewhere. The egg hatches in due course, and the young larva commences to feed on the paralysed cockchafer larva in such a manner that the latter does not die until the Scoliid larva is mature.

Scoliidæ are beneficial insects, as they destroy many injurious cockchafer larvæ.

Phytalus smithi (*Melolonthidæ*), whose larvæ feed on the roots of sugar cane, was accidentally introduced into Mauritius from the West Indies. The insect became a pest, but was effectively controlled by importing, from the West Indies, *Tiphia parallela*, which is a specific check on *Phytalus*.

Sapygidæ.

No constriction between first and second abdominal segments. Posterior legs short; eyes emarginate on inner side. Both sexes winged.

This is a small family of insects, and apparently nothing is known of their habits.

According to Fabre's observations, *Sapyga* lives at the expense of the bees—*Osmia*—the *Sapyga* larvæ destroying the bee's egg and feeding on the material supplied by the latter for its own young. The writer has observed the British *Sapyga 5-punctata* frequenting an old beech stump where there was a large community of the Sphegid *Pemphredon lugubris*.

There are only two British species recorded—*Sapyga 5-punctata* and *S. clavicornis*. Both are fairly common.

They are of no economic importance.

Mutillidæ (including *Methocidæ* and *Myrmosidæ*).

Male. Pronotum reaching tegulæ. A constriction between first and second abdominal segments. Middle coxæ contiguous. Middle tibiæ with two apical spines. Female: wingless; ant-like but without abdominal nodes.

The *Mutillidæ* appear to be common and widely distributed in the tropics, especially in South America, though they are not so much in evidence in the temperate regions.

The male *Mutillidæ* somewhat resemble Scoliids in being fairly large and brightly coloured; they can be distinguished however, by the two tibial spines and the position of the middle coxæ. Both sexes are covered with short, brightly coloured hairs. The general colour scheme is black with red, golden, or white bands and spots; some species are of a uniform bright-red colour. Unlike the majority of insects, the male is slightly larger than the female, and is often differently coloured. The females may be mistaken for ants, but the absence of abdominal nodes and the bright pubescence of the former at once distinguishes them from that family. The sting is long and inflicts a very painful wound.

Fig. 175.—A Mutillid ♀. (× 4.)

The antennæ are twelve-jointed in the female and thirteen-jointed in the male. The thoracic segments are not usually distinct in the female when viewed from above; the male, however, has these segments quite distinct. The nervures do not reach the outer margin of the fore-wings in the typical forms, and in the genus *Apterogyna* the nervures are more or less confined to the basal area. Very rarely the wings in the male are rudimentary or absent.

Little is known of the life-histories of the *Mutillidæ*, but it is believed that they are all parasitic on Aculeate *Hymenoptera*.

Mutilla europæa is known to be parasitic on species of *Bombus*; the egg is laid in the cell of the bee and the resulting larva feeds on the bee larva as a true parasite: the stored provisions, if any, in the host's cell are not utilized by the parasite.

E. André has monographed the *Mutillidæ* in *Genera Insectorum*, Fasc. 11 (1903).

It should be mentioned here that two families, *Methocidæ* and *Myrmosidæ*, have been formed. André, however, places them as sub-families of the *Mutillidæ*, whereas many authors include the *Methocidæ* with the *Thynnidæ*. In both *Methoca* and *Myrmosa* the female is wingless, and in the male the

nervures of the fore-wing extend to the outer margin. The *Methoca* female differs from the typical Mutillid in having the thoracic segments distinct.

Over 1,800 species have been described, of which four are British; they are *Mutilla europæa*, *M. rufipes*, *Myrmosa melanocephala*, and *Methoca ichneumonides*. None are common.

The *Mutillidæ* are of no economic importance.

Thynnidæ.

Like Mutillidæ. Male winged; the pronotum reaching the tegulæ, the nervures extending to the outer margin of the wings. Female wingless; the thoracic segments distinct.

This is rather a small family and appears to be confined to Australia, New Guinea and the adjacent islands, South America, and California.

The wingless female has very short and somewhat curled antennæ, and differs greatly from the male. A small process of the mesosternum separates the middle coxæ, and the middle tibiæ are furnished with two apical spines.

Nothing appears to be known of the habits of these insects. Froggatt believes them to prey on subterranean Lamellicorn larvæ.

The family has been monographed in *Genera Insectorum*, Fasc. 105 (1910), by R. E. Turner.

No British species have been recorded, and the family is of no economic importance.

Pompilidæ (*Psammocharidæ*).

Digger-wasps.

Pronotum reaching the tegulæ. Posterior legs long.

This large family is found in nearly all parts of the world.

The *Pompilidæ* are easily recognized in the field; they frequent sandy places, and may often be seen running rapidly

over the ground, their wings and antennæ being in a constan state of vibration. They are perhaps the most restless o insects, running and taking quick, short flights as they searc for the spiders which they provide for their young. Pompilid are usually black or metallic, sometimes marked with red some of the tropical forms exceed two inches in length. Th sting is severe. The antennæ are moderately long and ofte curled, especially after death ; the wings have a well-develope system of venation and are often smoky or metallic. Th long legs, especially the posterior pair, are the best diagnosti features of the family.

Spiders form the chief prey of the *Pompilidæ*. The femal

Fig. 176.—A Pompilid, showing the long posterior Legs. (× 1½.)

wasp searches for her prey, and having found it, stings it i such a manner that it is paralysed and incapable of furthe action. The spider is then dragged to some convenient hol or the wasp prepares a subterranean cell, and an egg is lai on it and the cell closed. The young larva on hatchin feeds on the body of the spider and when mature pupates i the cell. In Britain the perfect insects appear in May an June.

There are thirty-two species found in Britain according t Saunders's catalogue of the British Aculeate *Hymenoptera*.

Although the *Pompilidæ* are extremely interesting, they ar of no economic importance.

Eumenidæ.

Mud-wasps.

Wings folded longitudinally; middle tibiæ with one spine at the apex, the claws dentate.

This family is widely distributed and fairly common over the greater part of the world.

Eumenids are rather small insects, slender in build, and usually exhibit yellow and black colours; many forms are, however, of a uniform reddish-brown colour. The antennæ are moderately long, elbowed, and twelve-jointed in the female—thirteen-jointed in the male. The mouth-parts are of the normal biting and sucking type, the mandibles being well-developed. The abdomen is generally rather smooth and long, the petiole being frequently very narrow and elongate. There are six visible abdominal segments (dorsally) in the female and seven in the male; the former is provided with an efficient sting. The longitudinal folding of the fore-wings when the insect is at rest is very characteristic of this family and the *Vespidæ*.

The *Eumenidæ* provide for their young by making mud cells and storing provisions therein. Both sexes are represented, but there is no worker caste. The females select a suitable hole, usually in an old wall, bank, or wooden post, and proceed to store up a supply of caterpillars which have been previously stung; the number of caterpillars allotted to each cell varies from three to eight according to their size. When sufficient food material has been collected an egg is laid and the cell closed, usually with mud. The larva on hatching feeds on the caterpillars and when mature pupates in a cocoon in the cell. This is briefly the life-history of the genus *Odynerus*; some of the tropical forms of the genus *Eumenes* construct elaborate cells of clay which are fixed openly on to any convenient object. In practically all cases, Lepidopterous caterpillars are selected as food for the young.

These wasps are parasitized to a great extent by *Chrysidæ*, Ichneumons, and *Tachinidæ*.

This family, along with the *Vespidæ* and *Masaridæ*, has been

monographed in *Genera Insectorum*, Fasc. 19 (1904), by K. W von Dalla Torre.

There are eighteen species of *Eumenidæ* recorded fron Britain, seventeen of these belonging to the genus *Odyneru* and the remaining species being *Eumenes coarctata*.

Odynerus callosus and *O. parietum* appear to be commor and widely distributed in England and their nests are ofter to be found in old brick walls.

The *Eumenidæ* are useful insects, as they destroy large numbers of caterpillars; with few exceptions, however, they are not common enough to be of much use to the agriculturist.

Eumenes maxillosa provisions its cells with the larvæ o *Prodenia*, the Egyptian cotton-worm.

Vespidæ.

Wasps.

Wings folded longitudinally; middle tibiæ with two apical spurs. Claws simple.

Although this family contains barely 600 species, wasps are generally abundant in all parts of the temperate and tropical regions of the world.

Wasps are moderate-sized insects and almost invariably exhibit warning colours, usually a combination of yellow and black, or reddish-brown and yellow. They are usually more heavily built than Eumenids and possess great strength and considerable powers of flight.

The antennæ are of moderate length, elbowed, with a long basal joint (scape), and are twelve-jointed in the queen and worker and thirteen-jointed in the male. The mouth-parts are well adapted for biting and sucking, the mandibles being strong and generally toothed; the maxillæ have a long outer lobe and a six-jointed palp. The hypopharynx is bilobed, rather short, and in conjunction with the outer lobes of the labium (paraglossæ) forms an efficient lapping tongue; the labial palps are four-jointed. The compound eyes are large and in some forms reach down to the base of the mandibles. The thorax is stout, the pronotum reaching back to the tegulæ,

The abdomen varies in shape, the petiole being long and narrow in most genera, but in *Vespa* and *Polistes* it is very short; dorsally there are seven visible abdominal segments in the male and six in the queen and worker. The latter forms are provided with a sting, which in some of the larger species is very severe indeed. It should be borne in mind, however, that the sting in these insects is only used as a weapon of defence and not of offence, as is the case with the "digger-wasps" and *Eumenidæ*. The social wasps are harmless enough if their nests are not disturbed.

There are generally three castes of social wasps, viz.: "queens" or fertile females, "workers" or sterile females, and males.

The male is the product of the unfertilized egg, and the female

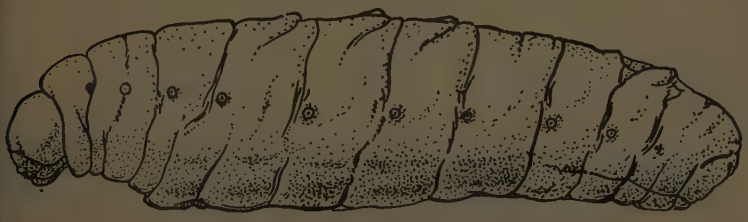


Fig. 177.—Larva of Vespid (*Vespa germanica*).

that of the fertilized egg; larvæ which are destined to become queens are provided with more food than those which are to become workers. The workers differ from the queens in being smaller and in having the ovaries reduced. Under certain circumstances, such as the premature death of the queen, the workers can become fertile and lay eggs, but as they are structurally incapable of being fertilized by a male, the product of these eggs is always of the male sex.

The life-history of the *Vespidæ* varies considerably according to the genus and climatic conditions. In Britain, however, the domestic economy of the wasps is very uniform. The queen wasp commences to lay the foundations of a nest towards the end of May; the site of the nest may be in the ground or suspended from the branch of a tree or bush. The material selected for the nest is wood-fibre reduced to a pulp by the jaws of the insect, to form, when spread out, a substance very

like paper. When a certain number of cells have been com pleted a fertilized egg is laid in each ; the eggs hatch in du course to legless and fleshy larvæ, which are fed by the quee on the juices of insects and on saccharine matter. When fu grown the larvæ spin a silken cap over the mouth of the ce and pupate, the perfect insects emerging soon after. For th first two months or so, only workers are produced, but toward the middle of August males and queens appear ; with th advent of cold weather in September and October the colon languishes, and the young queens, which may number 300 o more, pair and seek winter retreats under the bark of tree or in some convenient position in houses and sheds. Shortl afterwards the males, workers, and the old queen die, and th whole cycle commences again next spring. The wasp com munities are thus strictly annual in this country.

The food of the adult insects is varied ; they are predaceou and are also exceedingly fond of saccharine substances.

There are seven species of wasps found in Britain ; they a belong to one genus—*Vespa*—and include the hornet (*Vesp crabro*), an insect which has become scarce in recent year except in the New Forest, Hampshire, where it is more o less undisturbed.

The *Vespidæ* have been monographed by Dalla Torre i *Genera Insectorum*, Fasc. 19 (1904). Saussure has also mono graphed the social wasps (1858).

In the early months of the year, wasps destroy enormou numbers of caterpillars and *Diptera* for the purpose of feedin their larvæ ; saw-fly larvæ and Noctuid moths are als attacked.

On the other hand wasps do considerable damage to fruit apples, pears and plums being particularly affected.

In England the wasp probably does more good than harm though it is difficult to make the farmer and fruit-growe realize this.

Vespa orientalis is useful as a destroyer of the Egyptia cotton-worm, but these large hornets occasionally do mis chief in India when they confine their attentions to silk worms.

Generally speaking, the economic value of *Vespidæ* depend on the crops that are grown in the neighbourhood. In fruit

growing countries they are probably pests; whereas in countries where cotton, and other crops which suffer from the attacks of caterpillars, are grown, the wasps must be regarded as beneficial insects.

Masaridæ.

Antennæ usually clubbed.

This family, which consists of ten genera, appears to be widely distributed, though scarce. They have been recorded from S. Europe, N. Africa and Egypt, Brazil, Mexico, the southern states of the U.S.A., and Australia.

The antennæ are short, the terminal joints forming a more or less distinct club. The wings are often pigmented, the anterior pair not being folded longitudinally, or if so, only imperfectly. The intermediate tibiæ are armed with two terminal spurs, and the claws of the tarsi are usually notched. The abdomen, which is large and stout, is attached to the thorax by a very short petiole; the general colour scheme is black, marked with yellow and red.

Very little is known of the habits of these insects; *Celonites* is known to build cells of earth fixed to plants.

Dalla Torre has monographed the family in *Genera Insectorum*, Fasc. 19 (1904), and classifies the *Eumenidæ*, *Vespidæ*, and *Masaridæ* as sub-families of the one family, *Vespidæ*.

Group VIII. *SPHECOIDEA*. Digger-wasps.

Pronotum not reaching the tegulæ; posterior legs short.

The fourteen families which constitute this group were previously classified under one family—*Sphegidæ*. The *Sphecoidea* may be distinguished from the *Vespoidea*, which they resemble closely, by the pronotum not reaching back to the tegulæ.

The group will be dealt with here as a whole, but notes on the food-habits of the more important genera will be mentioned. The following is a list of the families, appended for reference purposes: *Ampulicidæ*, *Nyssonidæ*, *Psenidæ*,

Oxybelidæ, Crabronidæ, Philanthidæ, Trypoxylonidæ, Mellinidæ, Sphecidæ, Larridæ, Astatidæ, Pemphredonidæ, Bembicidæ, Cerceridæ.

The *Sphecoidea* is a very extensive group, representatives being found in nearly all parts of the world.

The external structure of the group is fairly uniform; the characters of the families are based largely on the wing venation, the shape of the labrum and eyes, the petiole, and other minor thoracic characters. In all the families, however, the pronotum is transverse and does not reach back to the tegulæ.

The antennæ are rather short and often curled. The legs are also comparatively short, the middle tibiæ being armed with one or two terminal spurs. The petiole is very short in some forms (*Bembicidæ*), but long and narrow in others (*Sceliphron*, *Ammophila*, etc). The sexes can always be readily distinguished, the females being provided with a sting. A curious modification of the legs is found in some male *Crabronidæ*, the anterior tibiæ being flattened out, so as to form a plate-like organ.

The life-history of these "digger-wasps" is fairly uniform throughout the group. Both sexes are represented, but there is no worker caste, the females alone providing for the future generation. The female wasps store up insects or spiders in mud cells or in burrows in the ground, somewhat after the manner of the *Eumenidæ* and *Pompilidæ*. The prey that is selected for the young ranges from crickets and caterpillars to Aphids. One of the most interesting species is *Sceliphron madraspatanum*; the life-history of this insect and many other solitary wasps has been worked out by Dutt (1912). The female *Sceliphron* selects a suitable site, often in houses, and constructs there about six or seven mud cells in which are stored spiders, previously paralysed by the wasp's sting. Dutt states that the wasp lays its egg on the first spider in the cell so that the larva on devouring it commences on the one above it until all the spiders have been accounted for; the wasp larva is then mature, with its head nearest the exterior. Pupation takes place in a silken cocoon in the cell, the perfect insect emerging about two weeks later.

With regard to the prey that is selected by the wasps for the young, almost every kind of insect appears to be suitable

For instance, species of *Sphex* generally catch crickets and locusts; *Ammophila*, caterpillars; *Sceliphron* and *Trypoxylon*, spiders; *Bembex*, *Crabro* and *Mellinus* attack *Diptera*, the former frequently attending horses and other animals for the purpose of catching *Tabanidæ*. *Ampulex* and *Astata* are known to attack cockroaches; the latter is also predatory on *Pentatomidæ*. *Tachytes* prefers *Orthoptera*, and in some cases they have been known to attack Mantids. Various beetles of the families *Curculionidæ*, *Chrysomelidæ*, etc., are attacked by species of *Cerceris*; *Philanthus* selects the formidable hive-bee as its victim; on the other hand, *Psen* and *Pemphredon* catch such easy prey as Psyllids and Aphids respectively.

The *Sphecoidea* are much subject to the attacks of Chrysids, Tachinids, Mutillids, and Ichneumons.

There are ninety-three species recorded in Saunders's catalogue of British Aculeate *Hymenoptera*.

Although the *Sphecoidea* have not been monographed in *Genera Insectorum*, there are several books relating to the habits of these insects, the most notable being Peckham's *Instincts and Habits of the Solitary Wasps*, 1898. This work also includes the *Pompilidæ*.

Although the domestic economy of the *Sphecoidea* is fairly uniform, the prey that is selected for the young is extremely varied, so that it is difficult to determine the economic value of the group. Those families which provision their nests with Aphids and cockroaches are no doubt beneficial insects. *Sceliphron* and *Trypoxylon* have been described as injurious, as they destroy large numbers of spiders; though until it has been proved that spiders appreciably reduce the numbers of destructive insects, these interesting wasps can hardly be termed injurious insects.

Group IX. *APOIDEA*. (*Anthophila*.) Bees.

Some hairs, especially those on the thorax, branched or plumose. First joint of the hind tarsi enlarged or dilated.

This group of insects, known as "Bees," is very well defined indeed.

The classification, however, is somewhat complex. Originally

all bees were placed in one family, *Apidæ* ; later on, the genera *Prosopis* and *Colletes* were separated from the rest and placed in a separate family called "*Colletidæ*," the justification for this being that the bees belonging to these genera have a short and broad tongue as compared with the long tongue of the true *Apidæ*. Saunders in his catalogue of British Aculeate *Hymenoptera* recognized three families, *Colletidæ*, *Andrenidæ*, and *Apidæ*. More recently, however, some seventeen genera have been promoted to family rank ; in a general way these families are fairly distinct both in structure and habits.

The group will be dealt with here as a whole, but a list of the families is appended for reference :—*Halictidæ*, *Andrenidæ*, *Dufoureidæ*, *Nomiidæ*, *Macropidæ*, *Panurgidæ*, *Nomadidæ*, *Euceridæ*, *Emphoridæ*, *Anthophoridæ*, *Hylæidæ*, *Colletidæ*, *Stelididæ*, *Megachilidæ*, *Ceratinidæ*, *Xylocopidæ*, *Apidæ*.

Bees are widely distributed throughout the temperate and tropical regions of the world ; although these insects are not common and familiar, the actual number of species in this group is less than one-third of the number of *Chalcidoidea*.

The external characters of the group are fairly uniform. The wings are always present in the perfect insects and are rather small in comparison with the rest of the body. The head is rather large ; very large in the *Megachilidæ*. The antennæ are, with few exceptions, short and strongly elbowed. The mouth-parts are very well developed in the flower-visiting species, especially in the *Apidæ*. The structure and mechanism of the mouth-parts of the hive-bee (*Apis mellifica*) have been treated in great detail by Cheshire, so that only a brief account of these organs need be given here. The mandibles in the worker hive-bee have their margins entire, and form useful implements for moulding the wax, but those of the queen and male are toothed. The maxillæ consist of a strong basal portion and a long flattened outer lobe (*galea*), the maxillary palp and the inner lobe being vestigial. The labium, however, is the most specialized organ in the mouth ; the hypopharynx is extremely long, grooved, but not tubular, and covered with parallel rows of small flattened hairs ; on each side of the hypopharynx lie the rather small paraglossæ (outer lobes of the labium), and then the long four-jointed labial palp

which, combined with the maxillæ and hypopharynx, form kind of sucking-tube.

In the lower bees such as *Prosopis* and allied genera the mouth-parts are reduced; the hypopharynx is short and broad and the maxillary and labial palps, which are six-jointed and four-jointed respectively, function as sensory organs. The first joint of the hind tarsi and the outer surface of the hind tibiæ are frequently dilated to form a pollen basket. Even in the cuckoo-bees the first hind-tarsal joint is abnormally enlarged, although the pollen-carrying apparatus is reduced or absent. The thorax is generally large, robust, and very hairy; the abdomen is also large and thick-set. The females are provided with a sting; and although this weapon is seldom employed, it is severe enough in some species, but very feeble in others; it is quite abortive in some of the social forms (*Melipona*).

The sexes can be readily distinguished, the males having seven abdominal segments and thirteen joints in the antennæ, while the females have only six abdominal segments and twelve joints in the antennæ, besides being furnished with a sting.

The life-history of the *Apoidea* falls into two main classes: (1) the flower-visiting bees, which make cells and store up honey and pollen; and (2) the "cuckoo-bees," which live at the expense of the former industrious insects. Only a brief account of the habits of the flower-visiting bees can be given here, as the domestic economy of the families differs so widely.

In the first family on the list, the *Halictidæ*, we find in the genus *Halictus* bees which are communal in habit; many species nest in the ground, several bees combining to form a common entrance and main burrow, after which each individual constructs in side galleries its own group of cells. These cells are provisioned with honey and pollen, and when a requisite amount has been accumulated an egg is laid in each and the cell closed. On hatching, the young larva feeds on the stored provisions, and when mature pupates in the cell.

In England both sexes emerge in the summer, and having paired, the males die while the females go into hibernation to reappear the following April and commence a fresh colony.

The life-history of *Andrena*, of the *Andrenidæ*, is somewha similar, but though the species of this genus are decidedl colonial, the communal habits observed in *Halictus* are not evidence. In the British *Andrena fulva* both sexes appe in April, the individual females making their own burrows an constructing their own cells, which are provisioned in a simil manner to the above. The young larvæ feed up rapidly an pupate in due course, the perfect insects emerging short afterwards; unlike *Halictus*, both sexes remain as adults the ground throughout the summer and winter, not leavin their burrows till the spring.

In the genus *Nomada* are to be found bees which live at th expense of other bees; the common British *Nomada ruficorn* is a "cuckoo" of the equally common *Andrena fulva*. Th former bears a great resemblance to some of the *Sphecoidea*, that it is slender, narrow-waisted, and almost naked, and being yellow- and black-banded. The *Nomada* appears spring at the same time as its host, enters its burrow, an deposits an egg in the provisioned cell of the *Andrena*. Th *Nomada* larva on hatching feeds rapidly, with the result th the *Andrena* larva dies of starvation; very rarely both ho and cuckoo reach maturity.

The *Anthophoridæ* are well represented in England *Anthophora pilipes*; it is a common insect in spring in mo parts of the country. The sexes differ widely, the male bei yellowish-brown with the intermediate tarsi clothed with lo silky hairs, while the female is black all over except in the hai of the hind tibiæ and tarsi, which are bright yellow. The bees nest, sometimes in large colonies, in burrows in the sid of sand-pits, banks, etc. The cells are stored in the usual w with honey and pollen. *Melecta armata* is a well-know cuckoo-bee which lives at the expense of *Anthophora*. T *Colletidæ* are represented by two common British gene *Colletes* and *Prosopis*; they may be distinguished from oth bees by their short bilobed hypopharynx. *Colletes* nests sandy places, often in large numbers, and lines its cells wi a slimy substance which hardens to form a more or l waterproof membrane. *Prosopis* bears no external rese blance to *Colletes*, and is black, slender, and almost nak The insect is not well adapted for pollen-collecting; it mak

its cells in the ground, in old walls, or in bramble stems, and provisions them in the usual manner.

Included in the *Stelididæ* is *Stelis minuta*, which is parasitic on a species of *Osmia*. According to Verhoeff the *Stelis* lays an egg in the provisioned cell of the host. The egg of *Stelis* is placed at a different level to that of the host, so that both larvæ hatch out and commence feeding on the provisions until they are consumed; the *Stelis* larva then settles the matter by killing and eating the *Osmia*. Another species of *Stelis* lives at the expense of *Chalicodoma*—the "Mason-bee." The bees in the family *Megachilidæ* collect pollen, not on the hind-legs, but on the under-side of the abdomen. Among the most interesting are the leaf-cutting bees belonging to the genus *Megachile*. These insects tunnel in the ground or in decayed wood and make their cells of fragments of leaves, chiefly from rose trees. The pieces of leaf are cut out by the female bee and carried to the nest, where they are cemented together to form the lining of the cell. The cells, which are provisioned with honey and pollen, are placed end to end in the wood.

Some of the tropical species of *Megachile* use clay instead of leaves, and nest in bamboo stems, or in any convenient tubular cavity, in houses. *Megachile* is the host of various species of cuckoo-bees of the genus *Cœlioxys*.

In the same family may be included the species of *Osmia*. The habits of these little bees are so diverse, not only in closely allied species, but even in any one species, that a detailed description here is impossible. Like *Megachile*, *Osmia* collects pollen on the under-side of the abdomen. *Osmia* is not particular as to where it forms its cells; they have been found in holes in walls and banks, in locks on doors, in snail-shells or in bramble-stems.

The life-history of *Ceratina viridissima* (family *Ceratinidæ*) in India has been studied by Dutt in some detail (*Mem. Dept. Agr. India*, Vol. IV, No. 4, 1912). The bees exhibit brilliant metallic colours, and have few hairs. The female bee tunnels in reed stems, bamboos, etc., and constructs therein a series of cells, each separated by a plug of plant-fibre. These cells are provisioned in the usual way with honey and pollen an egg being laid in each. According to Dutt the complete life-

history from egg to imago occupies from twenty-four to thirty-five days. One species of *Ceratina* is found in Britain, but it is rare.

The *Xylocopidæ* are large insects and are commonly named "Carpenter-bees." They nest in dry timber or reeds, forming galleries in which they construct their cells. The cells are separated from one another by plugs of sawdust cemented together. The cells are stored in the usual way with pollen; there is generally only one brood a year in Europe. *Xylocopa violacea* is found as far north as Paris, and has once occurred in England, but was probably imported from the Continent. The bees belonging to this family are among the largest and most brightly coloured *Apoidea* in the world.

The *Apidæ* include *Bombus*, the "Bumble-bees," *Psithyrus* their cuckoos, and the honey-bees, both wild and domesticated.

The life-history of the bumble-bees has been fully worked out by Sladen; it is not unlike that of our social wasps in that the colonies are annual. The fertilized queen bee emerges from its winter retreat in spring and founds a nest either on the ground or in a deserted mouse-hole; the situation varies according to species. The nest consists of moss or dry grass, in the centre of which the waxen cells are placed. Only workers are produced in the early months of the year, but later on males and young queens make their appearance. With the advent of cold weather the young queens burrow into the ground to pass the winter, the males, workers, and the old queen dying.

Bumble-bees are very industrious, collecting honey and pollen from dawn till dusk; they are useful insects, as they can fertilize red clover and other flowers with deep-seated nectaries.

The next genus to be considered is *Psithyrus*; they are cuckoos of *Bombus*, the queens entering the early nests of the latter and laying eggs in their cells. *Psithyrus* resembles *Bombus* to a great extent in being large and hairy, and banded with yellow or red and black. They may be distinguished from *Bombus* in having the outer surface of the hind tibia convex and hairy while *Bombus* has this portion of its anatomy flattened and shining. The wings of *Psithyrus* are often smoky or iridescent. The *Psithyrus* queen (or rather "female," as there is no worker

caste) hibernates as an adult in the ground and emerges in spring to search for nests of *Bombus* ; each species of *Psithyrus* is generally attached to one species of *Bombus*, which it mimics closely. Having found the nest of the host, the *Psithyrus* kills the *Bombus* queen, provided that there are sufficient workers in the nest to rear the inquiline's larvæ. On the death of the *Bombus* queen, the *Psithyrus* reigns supreme until the end of the season, when the males and females leave the nest and pair, the former dying and the latter going into hibernation. As the *Bombus* queen is killed early in the season, no males or queens are reared from a *Psithyrus*-infested nest.

The next insects under consideration are the hive- or honey-bees ; these belong to the genus *Apis*, of which the most important species is *Apis mellifica*—the common hive-bee. This bee probably originated in South Europe, being introduced into Britain and America.

A bee community normally consists of one functional queen and several thousand workers, males or " drones " being produced at certain times of the year. Young queens are also produced, but if the community is comparatively small, these young queens are stung to death by the old queen ; it is interesting to note that the sting of the queen bee is curved downwards, while that of the worker is straight.

If however the colony is getting too large for the hive or nest, the young queens are protected by the workers from the attacks of the old queen. Then the phenomenon of " swarming " occurs. This is the exodus from the hive of the old queen accompanied by several thousand workers ; these seek new quarters and commence a fresh colony.

One of the young unfertilized queens in the hive, having killed the others, leaves it for her nuptial flight, when she is fertilized by a drone bee. Although many drones are produced, only one is necessary ; but it is interesting to note that it is the strongest and swiftest drone that succeeds in pairing with the queen, so that in all probability his strength and flying powers will be transmitted to the young. The fertilized young queen returns to the hive and commences to take up her duties. Now that the drones have fulfilled their purpose in life, they are killed by the workers, as they do no work in the hive, and would only consume food required for

the winter. This is briefly the social economy of the hive-bee, but there are many other interesting details concerning swarming, etc., which it is impossible to give here. It should be noted that the hive-bee communities are not annual, as is the case with *Bombus* and *Vespa*, but the queen and a certain number of workers live through the winter and start collecting pollen in April; a fine sunny day in February or March, however, will tempt them out.

The life-history of the hive-bee is somewhat similar to that of the other *Apoidea*; the eggs are laid in wax cells made by the workers, and the larvæ are fed on honey and pollen. Larvæ destined to become queens are reared in larger cells and are fed on a more nutritious substance known as "royal jelly."

The time taken to complete the life-history from egg to worker is about three weeks, slightly less for a queen, and more for a drone.

There are several distinct races or varieties of *Apis mellifica* which are worth mentioning; of these the most important are the Italian bee—*ligustica*—and the Cyprian bee—*fasciata*—which comes from the Eastern Mediterranean and Egypt; these varieties interbreed freely.

There are three species of *Apis* worthy of note from India. *Apis dorsata* is a large species, very savage in disposition, and is only semi-domesticated in parts of India, but they yield good honey and wax. It builds a large, single comb, sometimes several feet across.

Apis indica is smaller than the above and seems to be more amenable to domestication.

Apis florea is quite small, and makes a single comb suspended from the branch of a tree; the workers' cells are on top of the comb, the drone and queen cells being placed at a lower level. The combs are too small to be of real economic value.

As yet there is no reference in *Genera Insectorum* relating to any of the families of the *Apoidea*. Saunders has listed the British species in the *Transactions of the Entomological Society of London* (1882–1884); this author has also described the life-histories of some of the commoner British bees in the work entitled *Wild Bees, Wasps and Ants*.

The domestic economy and morphology of the British

species of *Bombus* and *Psithyrus* have been studied in great detail by Sladen in *The Humble Bee* (1912).

The British species of *Apoidea* number about 212.

There are no pests in this group: the utility of the hive-bee in supplying honey and wax is well known to every one; in the pollination of flowers, however, the bees are of still greater service. Some species of *Megachile* have sometimes been recorded as being injurious to rose trees, but the actual damage that is done is negligible.

Group X. *FORMICOIDEA*. (*Heterogyna*.) Ants.

First abdominal segment (and sometimes second abdominal segment) forming a node or scale strongly differentiated from the remaining abdominal segments.

The *Formicoidea* cannot be confused with any other group of *Hymenoptera*. The insects belonging to this group are among the commonest and most numerous creatures in the world.

Ants are mostly social—males, females, and workers being usually represented—hence the old name "*Heterogyna*," referring to the two forms of the female.

Unlike the other large groups of *Hymenoptera*, the classification is very simple, there being but one family—*Formicidæ*—with five sub-families.

Formicidæ.

Ants are widely distributed and common in nearly all parts of the world.

The head is large in proportion to the rest of the body, but the size varies considerably according to caste. The antennæ are very strongly elbowed in the ♀ and ☿ and often clubbed. The mandibles are usually very strong, many-toothed, and can act independently of the other mouth-parts. The maxillæ, which have both an outer and an inner lobe, bear a one- to six-jointed palp. In the thorax the median segment or "epinotum," as it is often termed, is well developed. Both males and females are usually provided with wings, though in some species the

male is wingless, and in others, but more rarely, the female also is wingless; workers are never winged.

The articulation of the abdomen to the median segment is of considerable importance to the taxonomist. The first abdominal segment (*petiole*) is shaped like a knot or a flat scale, at the base of which is attached the second abdominal segment: the segments following the petiole constitute the *gaster*. In the *Myrmicinæ* and some *Dorylinæ*, the second abdominal segment (*post-petiole*) is somewhat similar to the petiole; in this case the third abdominal segment and the succeeding segments constitute the gaster. (Fig. 179.)

The sharp differentiation of the petiole (and the post-petiole if present) from the gaster is the best character for identifying ants.

The females and workers in the sub-families *Myrmicinæ*, *Ponerinæ*, and *Dorylinæ*, are provided with a serviceable sting.

The sexes can be distinguished in several ways: the males generally have one joint more in the antennæ than the females and workers, but this is not always the case. The eyes of the male are usually larger, the body more slender, and the mandibles smaller and weaker than is the case with the females and workers. The most obvious distinction, however, is the well-developed genital armature of the male.

In most species of ants there are three well-defined castes, viz. male, female, and worker; in a few cases the worker is absent (*Anergates*). There are, however, a bewildering series of forms of each caste which have received special names. Intermediates between each caste are known. "*Ergatandromorph*" is the name applied to an ant which exhibits both male and worker characters; similarly a "*gynandromorph*" exhibits male and female characters.

The habits of ants, especially in the tropics, are so diverse that it is impossible to give an account of them here. Nearly all ants are social, often making huge nests containing thousands of individuals. These colonies are more or less permanent year after year.

At certain times of the year, winged males and females leave the nest, sometimes in great numbers; copulation takes place in the air, and when the insects descend to the ground the male detaches himself from the female and in a short time usually

dies or is eaten by birds. The female sheds her wings and commences to found a new colony by burrowing into the ground or selecting some other suitable quarters under stones or behind the bark of trees, etc. Having constructed a small chamber she lays some eggs, and, according to Wheeler, nourishes the young larvæ on a "salivary secretion derived by metabolism from her fat-body and wing-muscles."

The first batch of workers are smaller than usual, but they carry on the work of the nest, enlarging it and obtaining food supplies for the female and the larvæ. Once a colony has started, the female does no more work in the nest, but lays eggs for a period of several years. The nests of ants differ from those of the social wasps and bees in that no combs are made for the larvæ; these latter have no fixed abode and are constantly moved from place to place by the workers, according to the weather, etc., conditions prevailing at the time.

Fig. 178.—*Polyrhachis simplex*, Egg, Larva, and Pupal Cocoon.

The food of ants is extremely varied; most of them are scavengers, feeding on any dead or dying insect which they may happen to encounter. Some species of *Formica* and *Eciton* have a weakness for the larvæ and pupæ of other ants. Aphids and Coccids are often protected by ants for their "honeydew." Some ants feed on seeds and fruits, and in the *Attini* (*Myrmicinæ*) the insects feed on the hyphæ of fungi, which they grow on leaves or some other suitable medium.

There are five sub-families in the *Formicidæ*:—*Ponerinæ*, *Dorylinæ*, *Myrmicinæ*, *Dolichoderinæ*, and *Camponotinæ*.

The *Ponerinæ*, which are considered to be the most primitive ants, appear to be fairly widely distributed, but are commonest in Australia; only two species are found in Britain. These ants are furnished with a sting in the female and worker, and the pupæ are enclosed in a cocoon. Only one abdominal node is present, but there is a constriction between the first and second gastric segments.

The *Dorylinæ* are mostly large ants, inhabiting the tropical

and sub-tropical regions, none being found in Britain. There is generally only one abdominal node, but the workers of *Eciton* and *Ænictus* have two ; in the males and females there is never more than one node.

The clypeus is generally much reduced, the antennæ being inserted near the front margin of the head. The male is abnormally large in comparison with even the largest worker. The females and workers are generally blind.

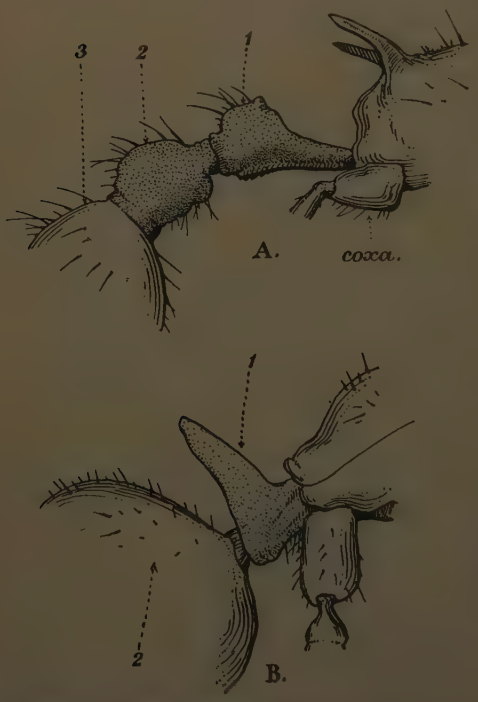


FIG. 179.—*Formicidæ*: Basal Segments of Abdomen.

A. Myrmica ruginodis (☿). *B. Formica rufa* (☿).

The domestic life of the *Dorylinæ* is very unlike that of the other sub-families : the colonies appear to have no fixed abode, but wander about, taking temporary lodgings under stones or under a fallen tree-trunk.

In this sub-family are to be found the "driver-ants" of the tropics ; these insects in the course of their wanderings frequently enter the habitations of man, necessitating a hasty retreat ; but the ants often render great service in clearing houses of rats, cockroaches, and other vermin. Only animal food is taken, saccharine and farinaceous food, beloved by other ants, being left untouched. The next sub-family—the *Myrmicinæ*—is a very extensive one indeed ; there are two well-marked abdominal nodes, and the workers are generally provided with an efficient sting. The *Myrmicinæ* are widely distributed, Britain possessing some seventeen species. *Myrmica ruginodis* is one of our com-

monest ants, being found in gardens and in uncultivated ground in most parts of the country.

In the *Dolichoderinæ*, which is represented in England by only one indigenous species, there are only four visible abdominal segments when viewed from above; the sting is generally vestigial and the pupæ are not enclosed in cocoons.

The *Dolichoderinæ* is a small sub-family, and may be passed over, though it should be mentioned that it includes the famous "Argentine Ant" (*Iridomyrmex humilis*).

In the *Camponotinæ* are to be found the most specialized ants; the insects appear to be widely distributed all over the world, Britain claiming two genera—*Lasius* and *Formica*, and thirteen species. The sting is reduced, but formic acid can be ejected from the abdomen into the wound made by the jaws of the insect. There is only one abdominal node, and there are five abdominal segments visible when viewed from above.

Formica rufa is a very common species in England, where it is termed the "Red Ant" or "Wood-ant." It constructs a large mound of small twigs, grasses, and pine-needles.

Formica sanguinea is the only slave-making ant that is found in Britain; it raids nests of *Formica fusca* and allied species and carries off the pupæ of *fusca* to its own nest. When the *fusca* workers emerge, they carry on the work of the *sanguinea* nest in apparent ignorance of the real nature of their masters.

Œcophylla smaragdina is the common red ant found in India, Africa, and the East generally. Nests are made in trees, the insects binding the leaves together with silk obtained from the larvæ; several ants combine to hold the leaves together with their mandibles and legs, while other workers within the nest hold their larvæ in their mandibles and move them backwards and forwards and from side to side so that the two edges of the leaf are brought together by a network of silk strands. The ants, though they are sometimes a nuisance and bite severely, are energetic insect-hunters. Scale insects are often maintained in captivity by ants, as their excretions are greatly valued.

The *Formicidæ* have been studied in great detail by W. M. Wheeler in *Ants: their Structure, Development and Behavior*,

Columbia University Press (1910). The following sub-families have been treated in *Genera Insectorum* by C. Emery :—Fasc. 102 (1910), *Dorylinæ* ; Fasc. 118 (1911), *Ponerinæ* ; Fasc. 137 (1912), *Dolichoderinæ* ; Fasc. 174 (1922), *Myrmicinæ*.

There are thirty-three species of ants recorded from Britain according to H. St. J. K. Donisthorpe's work entitled *British Ants : their Life-history and Classification* (1915).

Most species of ants are beneficial to man ; they remove dead or dying insects, and the driver ants (*Dorylinæ*) effectually clear houses of vermin, besides destroying numbers of grass-hoppers and locusts. There are however a few ants which are very destructive ; chief among these is the Argentine ant (*Iridomyrmex humilis*). As its name implies, this insect originated from the Argentine, whence it was imported to the Southern States of America. Lately it has appeared in great numbers in Madeira and has actually come to Britain, where it established colonies in a house in Belfast ; it has also been found in Eastbourne. It is in America, however, that its presence is most troublesome ; not only is it a household pest devouring almost everything eatable, but it protects, for the sake of honey-dew, the Aphids and Coccids occurring on orange trees, sugar cane, cotton, and other plants.

The control measures adopted have been fairly successful. When houses are infested, tape soaked in a solution of corrosive sublimate (mercuric chloride), and fastened round the legs of beds and tables, will prevent the ants ascending : dishes containing naphthalene or mineral oil placed under the legs of furniture has a similar deterrent effect. To prevent the ants ascending trees, grease-bands containing powdered sulphur have been used with success. Arsenical syrups have also been effective, as the Argentine ant has a weakness for saccharine substances.

For further information concerning the Argentine ant, the Bulletins of the U.S. Dept. Agr. (Entomology) should be consulted.

Some of the fungus-growing ants, notably *Atta texana*, do considerable damage to vegetation when they cut off leaves for the purpose of using them as a fungus-growing medium. Cotton, fruit trees, and cereals have been defoliated by these ants. To control the insects, the nests should be located and

a solution of potassium cyanide in water should be poured into the openings.

Garden ants, which raise unsightly hills and are generally a nuisance, may be destroyed by drilling a hole about a foot deep in the nest with a stick and pouring in carbon bisulphide or a solution of potassium cyanide, and then plugging up the hole so that the fumes will not escape. *Dorylus orientalis* is another pest, found in India, Ceylon, and the Malay region ; the workers burrow in the ground after the manner of Termites and attack the roots of ground-nuts and various *Cruciferæ*. The vegetarian habits of these ants is in marked contrast to the carnivorous habits of the other *Dorylinæ*.

Solenopsis geminata is the " Fire-ant " ; originally found in the warmer parts of America, it has now been introduced into the tropics of both hemispheres. The sting is severe and the ant does not hesitate to use it. These ants are to a certain extent harvesters, but they also subsist on animal matter. Often a serious nuisance in America, the fire-ant can be controlled by pouring carbon bisulphide or a solution of potassium cyanide into the nest. In India *Solenopsis* has been introduced into warehouses to check the ravages of Termites.

Among the household pests, *Monomorium pharaonis* (*Myrmicinæ*) is one of the most important ; it is a small reddish ant, and when it occurs in large numbers is an intolerable nuisance. The insects form their nests in some sheltered recess behind walls or under floors, and wander all over the house searching for food.

SCIENTIFIC INDEX

The object of the index is to provide a reference to the position of each genus nd family : genera are indexed only in reference to their systematic position nd not where mentioned incidentally elsewhere.

Names in italics are synonyms : figures in italics refer to text-figures : Roman igures refer to plates.

calyptratæ, 440
canthomeridæ, 433
centropus, 383, 385
cerentomidæ, 5
cerentomon, *3*, 5
cerentulus, 5
chetidæ, 39, 72
chorutes, 17, 18
chorutidæ, 17
cidia, 443
cræa, 343
crænæ, 344
cridiidæ, 39, 54
cridium, 55, *57*, 58
crocinus, 200
cronyctinæ, 353, 354
culeata, 478, 480, 501
dela, 392
dephaga, 118
dimeridæ, 149
doretus, 215
doxus, 196
ëdes, 419
Egeria, 389
Egeriidæ, 388
Egocera, 350
Egialitidæ, 178
Enictus, 526
Eolothripidæ, 225
Eolothrips, 224
ëpophilidæ, 248
ëpophilus, 248
ëpus, 248
Equipalpia, 314
Eschna, I
Eschnidæ, 31
Eschninæ, 28
Eschnines, 30
ganaidæ, 356
gapanthia, 201
garistidæ, 350
gdistis, 387
Aglycyderidæ, 208
Agnatha, 24
Agrilus, 173
Agrionidæ, 32
Agriotes, 175
Agriotypus, 495
Agromyzidæ, 446
Agrotinæ, 352, 353
Agrotis, 336, 352
Alaus, 174
Alcides, 206
Aleuropteryginæ, 299
Aleurodes, 278
Aleurodidæ, 276
Alleculidæ, 180
Alsophila, 364
Alucitidæ, 387
Alysia, *497*
Alysiidæ, 496
Amathusiinæ, 343
Amatidæ, 348
Amblycera, 102
Ammophila, 514
Amorphoscelis, 46
Amphotis, 141
Amphizoidæ, 121
Ampulex, 515
Ampulicidæ, 513
Anabrus, 71
Anacampsis, 393
Anamerentoma, 3
Anaphe, 332, 336, 360
Anasa, 239
Anastrepha, 443
Ancylis, 391
Andrenidæ, 516
Andrena, 518
Andricus, 487
Anergates, 524
Aneurus, 243
Anisolabis, 107
Anisoptera, 29, 31
Anisozygoptera, 31
Anobiidæ, 167
Anomala, 215
Anopheles, *413*, 419
Anoplognathus, 215
Anoplura, 226
Anoura, 17
Antestia, 238
Antheræa, 331, 334, *365*
Antherophagus, 144
Anthicidæ, 191
Anthocoridæ, 250
Anthomyiidæ, 452
Anthonomus, 206
Anthophila, 515
Anthophora, 518
Anthophoridæ, 516
Anthores, 200
Anthrenus, 152, 153
Anthribidæ, 202
Anurida, 18
Apanteles, 497
Apate, 169
Apatura, 342
Aphelinidæ, 491
Aphelopus, 503
Aphidæ, 268
Aphidinæ, 275
Aphidoletes, 424
Aphis, 270, 275
Apidæ, 516, 520
Apioceridæ, 434
Apion, 206
Apis, 520
Apochrysidæ, 306
Apogonia, 215
Apoidea, 515
Aptera, 1
Apterogyna, 506
Arræcerus, 202
Aradidæ, 242
Arbela, 371

Arbelidæ, 370
Arctia, *349*
Arctiidæ, 348
Arctiinæ, 349
Argina, 357
Argynnis, *342*
Argyrotypidæ, 371
Arthropleona, 17
Arixenia, *108*
Arixeniidæ, 108
Aromia, 199
Ascalaphidæ, 312
Ascalaphus, IV
Aschiza, 438
Ascodipteron, 464
Asilidæ, 434
Assmuthia, 12
Astata, 515
Astatidæ, 514
Asterochiton, *277*, 278
Asterolecanium, 287
Ataxia, 201
Athalia, 485
Atherix, 430
Athous, 175
Atomaria, 144
Atractocerus, 166
Atropos, *96*, 97
Atta, 528
Attacus, 331, 334, *366*
Attelabus, 205
Attini, 525
Auchmeromyia, 454
Aulacophora, 197
Aulacus, 498
Aularches, 55
Austroperlidæ, 23

Bacillus, 51
Bætisca, 26
Bagrada, 238
Balaninus, 206
Balanogastris, 206
Banchidæ, 494
Barathra, *351*, 354
Barynotus, 206
Bathysia, 131
Batocera, 200
Beckia, 19
Belionota, 173
Belippa, 377
Belostoma, 255
Belostomidæ, 254
Belytidæ, 489, 490
Bembex, 515
Bembicidæ, 514
Berothidæ, 303
Berytidæ, 239
Bethylidæ, 502
Bibio, 427
Bibionidæ, 426
Biorhiza, 487
Bittacidæ, 318
Bittacus, II
Blaps, 177
Blastophaga, 493
Blatta, 44
Blattella, 45
Blattidæ, 39
Blepharipa, 459
Blepharoceridæ, 428
Blissus, 240
Boarmia, 363
Bolitophila, 425
Bombus, 520
Bombycidæ, 366
Bombyliidæ, 436
Bombyx, 331, 332, *366*, 367
Boopia, 102
Borboridæ, 450
Boreidæ, 318
Boreus, II
Boriomyia, III
Bostrichus, 169
Bostrychidæ, 168
Brachycera, 430
Brachydeutera, 449
Brachytrypes, 75, 76
Brachartona, 380
Brachytarsus, 202
Braconidæ, 496
Brahmæidæ, 367
Brassolinæ, 341, 343
Braulidæ, 464
Brenthidæ, 201
Brontes, 142
Bruchidæ, 193
Bruchophagus, 492
Bucentes, 459
Buprestidæ, 171
Buprestis, 173
Byrrhidæ, 153
Byturidæ, 139
Byturus, 140

Cælænomenodera, 197
Cænis, 27
Calamoceratidæ, 314
Calobata, 441
Calocoris, 252
Caloptenus, 59
Calopterygidæ, 32
Calopteryx, I
Callaphis, 275
Callidulidæ, 380
Callimomidæ, 491
Calliphora, 455
Callirhipis, 161
Calyptratæ, 452
Campodea, 7, *8*
Campodeidæ, 8
Camponotinæ, 525
Campsurus, 24, 26
Camptosomes, 195
Cantharidæ, 162
Cantharidæ, 188
Cantharis, 163
Capitonidæ, 496
Capniidæ, 23
Caprinia, 386
Capsidæ, 251
Capua, 391
Carabidæ, 120
Caradrina, 354
Carausias, *51*
Carpocapsa, 390
Carpomyia, 443
Carpophilus, 141
Cassida, 197
Cassidinæ, 196
Castniidæ, 336, 378
Catochrysops, 345
Catoprochotidæ, 144
Catoxantha, 173
Cebrioninæ, 174
Cecidomyia, 425
Cecidomyiidæ, 423
Celonites, 513
Celyphidæ, 450
Cephidæ, 480
Cephus, 481, 482
Cerambycidæ, 197
Ceraphronidæ, 489, 490
Cerataphis, 275
Ceratina, 519
Ceratinidæ, 516
Ceratitis, 443, 445
Ceratocampidæ, 367
Ceratocombidæ, 248
Ceratophyllus, 469
Ceratopogoninæ, 421
Ceratopsyllidæ, 470
Cerceris, 515
Cercéridæ, 514
Cercopidæ, 261
Cerococcus, 287
Cerophytinæ, 174
Ceroplastes, 286, 287
Ceroplatus, 425
Cerura, *361*
Cetonia, 215
Cetoniini, 215
Ceutorhynchus, 206
Chalcididæ, 491
Chalcidoidea, 491
Chætocnema, 197
Chætopsis, 442
Chalcodermus, 206

Chalcosiinæ, 319
Chalicodoma, 519
Chapra, 347
Charæas, *351*, 352
Chauliodes, 291
Cheimatobia, 363
Chelisoches, 107
Chermes, 276
Chermidæ, 264
Chilo, 384, 385
Chilomenes, 152
Chironomidæ, 421
Chironomus, 422
Chirotonetes, 26
Chlamydinæ, 196
Chlorochroa, 238
Chloridea, 353
Chlorita, 263
Chloroperla, I
Chloropisca, 447
Chlorops, 447
Chortophila, 453
Chrotogonus, 55
Chrysidæ, 500
Chrysidoidea, 500
Chrysis, 501
Chrysobothris, 173
Chrysomelidæ, 194
Chrysomyia, 454, 455
Chrysopa, III
Chrysopidæ, 304
Chrysops, 432
Chrysopolomidæ, 375
Cicada, *257*, 258
Cicadidæ, 257
Cicadula, 263
Cicindela, 119
Cicindelidæ, 119
Cimex, 249
Cimicidæ, 249
Cioidæ, 171
Cistelidæ, 180
Clambidæ, 131
Clavicornia, 137
Cleonus, 206
Cleridæ, 165
Clidogastra, 451
Clivina, 121
Cloeon, I, 25
Clothilla, 96, 97
Clytus, 201
Clytrinæ, 195
Cnethocampa, 360
Coccidæ, 279
Coccinellidæ, 150
Coccus, 287
Cochlididæ, 376
Cœliodes, 206
Cœlioxys, 519
Colaspidema, 197
Colaspis, 196, 197
Coleoptera, 111
Collembola, 14
Colletes, 518
Colletidæ, 516
Collyris, 120
Colobathristidæ, 240
Colpocephalum, *99*, 102
Colydiidæ, 148
Conotrachelus, 206
Conchaspis, 287
Conchylis, 391
Coniopterygidæ, 299
Conopalpus, 184
Conopidæ, 440
Conops, *411*
Conorhinus, 247
Contarinia, 424, 425
Conwentzia, III, 300
Coptops, 201
Coptotermes, *86*
Cordulines, 30
Cordylobia, 454
Cordyluridæ, 451
Coreidæ, 238
Corixa, 256
Corixidæ, 256
Corrodentia, 33, 81, 95
Corydalis, 291
Corylophidæ, 133
Cosmophila, 353
Cossidæ, 336, 372
Cossus, 373
Crabro, 515
Crabronidæ, 514
Crambidæ, 384
Crambinæ, 384
Craponius, 206
Crepidodera, 197
Criocerinæ, 194
Crioceris, 197
Croce, 97, 310
Cryphalus, 208
Crypsithyris, 395
Cryptinæ, 495
Cryptocephalus, 195
Cryptocerata, 252
Cryptochætum, 446
Cryptophagidæ, 144
Cryptorrhynchus, 206
Cryptostomes, 196
Ctenocephalus, 469
Ctenolepisma, 13
Cucujidæ, 141
Culex, *407*, *419*
Culicidæ, 418
Cupedidæ, 126
Curculionidæ, 203
Cursoria, 38
Cyathoceridæ, 155
Cyclica, 195
Cyclopodia, 463
Cyclorrapha, 398, 438
Cydia, 337, 390
Cylas, 206
Cylindrodes, 73
Cylindrotomini, 415
Cymatophoridæ, 359
Cynipidæ, 486
Cynipoidea, 486
Cynips, 488
Cyphonidæ, 159
Cyphoderes, 19
Cyrtidæ, 433

Dactylopius, 287
Dacus, 443, 444
Dalceridæ, 377
Danainæ, 343
Dascillidæ, 159
Dascyrtocara, *216*
Dasychira, *355*
Dasyllis, 435
Dasyneura, 425
Delphax, 260
Deltocephalus, 263
Dermaptera, 103
Dermatobia, 454
Dermatophyllus, 468
Dermestes, 153
Dermestidæ, 152
Derodontidæ, 146
Desiantha, 206
Deuterophlebiidæ, 429
Dexiidæ, 460
Diabrotica, 197
Diapriidæ, 489, 490
Diastrophus, 488
Diatræa, 384, 385
Dicerca, 173
Dichocrocis, 386
Dictanomyia, 416
Dilaridæ, 298
Dioninæ, 343
Diopsidæ, 451
Diparopsis, 353
Diphucephala, 197
Diploptera, 502
Diploschema, 200
Diplosis, 425
Diptera, 397
Discophorinæ, 343
Disphinctus, 252
Ditoma, 148
Dixidæ, 418
Docophorus, 102
Dolichoderinæ, 525
Dolichopodidæ, 437
Dolycoris, 238

Donaciinæ, 194
Donaconethis, *33*
Dorylinæ, 525
Dorylus, 529
Drepanepteryx, 297
Drepanidæ, 381
Drepanulidæ, 381
Drilinæ, 163
Drosicha, 287
Drosophilidæ, 448
Dryinidæ, 503
Dryopidæ, 156
Dufoureidæ, 516
Dynastini, 214
Dyscritina, 104
Dysdercus, 241
Dytiscidæ, 123
Dytiscus, *123*

Earias, 337, 353
Echidnophaga, 470
Echinophthiriidæ, 230
Eciton, 525, 526
Ectobius, 44
Elachertidæ, 491
Elaphidion, 200
Elasmidæ, 491
Elater, *173*
Elateridæ, 173
Elenchus, 218
Eleodes, 178
Elmidæ, 156
Embiidæ, 33
Embiomyia, 459
Embioptera, 33
Emenadia, 188
Emphoridæ, 516
Empidæ, 436
Empoasca, 263
Encyrtidæ, 491
Endaphis, 424
Endomychidæ, 149
Endomychus, *149*
Endopsylla, 424
Endromidæ, 374
Eneopterinæ, 80
Ennomos, 364
Entedontidæ, 491
Entomobryidæ, 18
Eosentomidæ, 5
Epepeotes, 201
Ephemera, 26
Ephemerida, 24
Ephemeroptera, 24
Ephestia, 337, 384
Ephippiger, 71
Ephydridæ, 449
Epiblemidæ, 368
Epicauta, 189
Epicopeiidæ, 368, 369
Epilachninæ, 150
Epinotia, 390
Epiophlebia, 31
Epiophlebiidæ, 31
Epitrix, 196
Erastiinæ, 353
Eremiaphila, 46
Eriococcus, 287
Eriocrania, 396
Eriosoma, 270
Eriosomatinæ, 275
Eristalis, 440
Erotylidæ, 143
Erycinidæ, 345
Eublemma, 351, *352*
Eucelis, 390
Euceridæ, 516
Eucharidæ, 491
Eucleidæ, 376
Eucneminæ, 174
Eudemis, 390
Eudesmus, 200
Eugaster, 67
Eulecanium, 287
Eulophidæ, 491
Eumenes, 509
Eumenidæ, 509
Euoxysoma, 492
Eupelmidæ, 491
Euphyllura, 268
Euplexoptera, 103
Eupodes, 194
Euproctis, 356
Eupterotidæ, 359
Eupteryx, 263
Euroleon, IV
Eurydema, 238
Eurymetopus, 102
Eurytomidæ, 491, 492
Euschemonidæ, 379
Eustheniidæ, 23
Eutermes, *82*, 89
Eutettix, 263
Eutrichocampa, 9
Euxoa, 336
Evalljapyx, 11
Evaniidæ, 498
Exelastis, 388
Exophthalmus, 206

Fannia, 452
Fidia, 196
Figitinæ, 488
Fœnus, 498
Forda, 275
Forficula, *104*
Forficulidæ, 103
Formica, 527
Formicidæ, 523
Formicoideæ, 523
Fulgoridæ, 259

Galeriadæ, 384
Galeriinæ, 384
Galerucella, 196
Galerucini, 196
Galgulidæ, 252
Gasteruption, 498
Gastropacha, *373*
Gastrophilus, 461
Gelechia, 337, 393
Gelechiadæ, 393
Gelechiinæ, 393
Geometridæ, 362
Georyssidæ, 155
Geotrupes, *213*
Gerris, *244*
Ghilianella, 247
Glenea, 200
Glossina, *405*
Glossininæ, 457
Glyphodes, 386
Gnorimoschema, 393
Gnostidæ, 129
Gongylus, *49*
Gossyparia, 287
Gryllidæ, 39, 72
Gryllinæ, 78
Grylloblatta, *72*
Grylloblattidæ, 38, 39,
Gryllotalpa, *77*
Gryllotalpinæ, 77
Gryllus, *73*, *75*
Guerinia, 287
Gymnocerata, 237
Gyrinidæ, 124
Gyropidæ, 102
Gyropus, 102

Hæmatobia, 456
Hæmatomyzidæ, 229
Hæmatomyzus, 229
Hæmatopinidæ, 230
Hadena, 354
Hadeninæ, 352, 354
Halictidæ, 516
Halictophagus, 218
Halictus, 517
Haliplidæ, 122
Halobates, 244
Halticinæ, 195
Haltica, 197
Harmolita, 493
Harpalus, 121
Harpax, 46
Hebridæ, 243
Hebrus, 243
Helicoconis, 300
Heliconiinæ, 343

Heliothis, 353
Heliothrips, 224
Helodidæ, 160
Helomyzidæ, 450
Heloridæ, 490
Helopeltis, 252
Helophorus, 158
Helops, 277
Helotidæ, 139
Hemerobiidæ, 296
Hemimeridæ, 38, 109
Hemimerus, *109*
Hemiptera, 232
Henicocephalidæ, 245
Hepialidæ, 395
Hepialus, 396
Herse, 358
Hesperia, 347
Hesperiidæ, 346
Heterocera, 337, 347
Heteroceridæ, 158
Heterocordylus, 252
Heterodoxus, 102
Heterogamia, 43
Heterogeneidæ, 376
Heterogyna, 523
Heterogynidæ, 370
Heteromera, 176
Heteromuricus, 19
Heteroneuridæ, 449
Heteronychus, 215
Heteroptera, 237
Heterusia, 380
Hierodula, *46*
Hieroglyphus, 58
Hippoboscidæ, 462
Hispa, 197
Hispinæ, 196
Histeridæ, 135
Holaniaria, 178
Homoptera, 256
Hoplocampa, 485
Hormaphidinæ, 275
Hyantinæ, 343
Hydrellia, 449
Hydrobius, 158
Hydrocampinæ, 385
Hydrometridæ, 243
Hydrophilidæ, 157
Hydropsychidæ, 314
Hydroptilidæ, 314
Hydroscaphidæ, 133
Hygrobiidæ, 122
Hylastes, 208
Hylemyia, 453
Hylesinus, 208
Hylobius, *203*
Hylœidæ, 516
Hylophilidæ, 191
Hymenoptera, 471
Hypatima, 394
Hypera, 206
Hyperetes, 96
Hypoborus, 208
Hypoderma, 461
Hypsa, 357
Hypsidæ, 356

Ibaliinæ, 488
Icerya, 287
Ichneumonidæ, 494
Ichneumoninæ, 495
Ichneumonoidea, 493
Idiocerus, 263
Ipidæ, 206
Inæquipalpia, 314
Inesida, 201
Inocellia, 292
Iridomyrmex, 527, 528
Ischnocera, 101
Isoscelipteron, 304
Isoptera, 81
Isosoma, 492, 493
Isotoma, 16, 18, 19
Ithomiinæ, 343
Ithone, II, III
Ithonidæ, 295

Japygidæ, 10
Japyx, *10*
Jassidæ, 263
Jassus, 263

Kermes, 287
Kakothrips, 224

Labia, 105, 107
Labidæ, 247
Labidura, 106
Lachnosterna, 215
Lachnus, 275
Lagoidæ, 376
Lagriidæ, 178
Lamellicornia, 209
Lamia, *198*
Lamiidæ, 200
Lamprosominæ, 196
Lampyrinæ, 162
Langelandia, 148
Languria, 143, 144
Laphria, 435
Lapromyia, 431
Lariidæ, 193
Larridæ, 514
Lasiocampidæ, 373
Lasioderma, 168
Lasioptera, 425
Lasius, 527
Laspeyresia, 390
Lathridiidæ, 146
Latumcephalum, 102
Lecanium, 287
Lemoniidæ, 345
Lepidocampa, 9
Lepidoptera, 321
Lepidosaphes, *281*, *283*, *284*, *285*
Lepisma, 7, *13*
Lepismidæ, 12
Leptidæ, 430
Leptinidæ, 132
Leptinotarsa, 196
Leptispa, 197
Leptobyrsa, 242
Leptoceridæ, 314
Leptogaster, 435
Leptoglossus, 239
Leptoperlidæ, 23
Leptops, 206
Leptostylus, 200
Lestes, 29
Lestidæ, 32
Leto, 395
Leucania, 336, 352
Leucops, 446
Leucospidæ, 491
Libellulidæ, 31
Libellulines, 30
Libytheinæ, 346
Ligyrus, 215
Limacodidæ, 376
Limnophilidæ, 314
Limnophilus, *316*, 317
Limonius, 175
Liotheidæ, 102
Liparidæ, 354
Lipeurus, 102
Lipoptera, 99
Lipura, 17, 18
Lissorhoptrus, 206
Lita, 392
Lithosiinæ, 349
Lithosiidæ, 348
Lixus, 206
Llaveia, 287
Lochmæa, 197
Locustidæ, 39, 66
Locustidæ, 39, 54
Lohita, 241
Lomaspilis, *363*
Lonchopteridæ, 438
Longitarsus, 197
Lophyrus, 485
Lopophus, 54
Lucanidæ, 211
Lucilia, 454, 455
Lycæna, 345
Lycænidæ, 344
Lycinæ, 162

Lyctidæ, 169
Lygæidæ, 240
Lygus, 252
Lymantria, 356
Lymantriidæ, 354
Lymexylonidæ, 166
Lyttidæ, 188

Machilidæ, 11
Machilis, 12
Macrodactylus, 215
Macroglossa, 358
Macropidæ, 516
Macrosiphum, 270, *273*, 275
Magdalis, 206
Mahasena, *369*
Malachiinæ, 164
Malacodermidæ, 162
Malacosoma, 374
Mallophaga, 99
Mallophora, 435
Mansonia, 419
Mantidæ, 39, 45
Mantis, 50
Mantispa, IV
Mantispidæ, 306
Margarodes, 287
Margarodinæ, 287
Maruca, 386
Masaridæ, 513
Mayetiola, 423, 424
Meconema, 68
Mecoptera, 318
Megachile, 519
Megachilidæ, 516
Megalopygidæ, 376
Megaloptera, 289
Megalothoracidæ, 20
Megalothorax, 20
Megastigmus, 492
Megistorhyncus, 433
Melandryidæ, 184
Melanoplus, 63
Melanotus, 175
Melasoma, 197
Melecta, 518
Meligethes, 141
Melipona, 517
Mellinidæ, 514
Mellinus, 515
Meloidæ, 188
Melolontha, *113*, 215
Melolonthinæ, 214
Melophagus, 462
Melyridæ, 164
Membracidæ, 260
Menopon, 101, 102
Merodon, 440
Meromyza, 447
Meropidæ, 318
Mesopsocus, 96
Metæcus, 187
Methoca, 506
Methocidæ, 505
Miastor, 423
Microcentrum, *69*
Microdon, 440
Microgaster, 497
Micropezidæ, 441
Micropterygidæ, 396
Miltogramma, 458
Mindarinæ, 275
Miridæ, 251
Moëcha, 200
Molannidæ, 314
Monohammus, 200
Monolepta, 197
Monommidæ, 180
Monomorium, 529
Monophlebulus, 287
Monophlebus, 287
Monotomidæ, 142
Monoxia, 197
Mordellidæ, 185
Mordellistena, 186
Morphinæ, 336, 343
Murgantia, 238
Musca, *413*, 454, 456
Muscaridæ, 461
Muscina, 455
Muscidæ, 453
Mutillidæ, 503
Mycetophagidæ, 147
Mycetophilidæ, 425
Mydæa, 452
Mydaidæ, 434
Mylabris, 189
Mymaridæ, 491, 492
Myodochidæ, 240
Myrientomata, 3
Myrmecophilinæ, 78
Myrmeleonidæ, 310
Myrmica, 526
Myrmicinæ, 525
Myrmosidæ, 505
Myrmosa, 506
Mytilaspis, *281*, *283*, *284*, *285*

Nabis, 247
Nacerdes, 183
Nasonia, *492*
Naucoridæ, 254
Naucoris, 254
Necrobia, 166
Necrophorus, 131
Neelidæ, 20
Neelus, 20
Nematus, *480*, 484, 485
Nemeobiidæ, 345
Nemestrinidæ, 433
Nemocera, 415
Nemoptera, IV, 310
Nemopteridæ, 309
Nemosoma, 138
Nemouridæ, 23
Neocastniidæ, 378
Nepa, 253
Nepidæ, 253
Nesiotinus, 102
Neuroptera, 294
Nezara, 238
Nicoletia, 13
Nilionidæ, 181
Nina, 310
Niponiidæ, 136
Nirmus, 102
Nitidulidæ, 140
Noctuidæ, 336, 350
Nolinæ, 350
Nomada, 518
Nomadidæ, 516
Nomiidæ, 516
Nonagria, 353
Nosodendridæ, 154
Nothochrysa, 306
Notiothaumidæ, 318
Notodontidæ, 360
Notonecta, 255
Notonectidæ, 255
Notoxus, 192
Nycteribiidæ, 463
Nymphalidæ, 341
Nymphalinæ, 343
Nymphes, IV, 308
Nymphidæ, 308
Nymphula, 385
Nyssia, *364*
Nyssonidæ, 513

Oberea, 201
Ocypus, *128*
Odonata, 28
Odontata, 197
Odontoceridæ, 314
Odynerus, 509
Œcanthinæ, 78
Œcanthus, 74, 75, 76, 7
Œcophoridæ, 394
Œcophorinæ, 394
Œcophylla, 527
Œdemeridæ, 182
Œstridæ, 461
Oinophila, 337, 394
Olibrus, 145
Oligarces, 423
Oligotoma, 33
Oligotomidæ, 35

Oligotrophes, 425
Omophlus, 178
Oncognathus, 252
Oncopeltus, 240
Oniscigaster, 25
Opatrum, 177
Ophideres, 331
Ophion, 494
Ophionidæ, 495
Orchesella, 19
Orchesia, 184
Orchestes, 206
Orgyia, *355*
Orneodidæ, 387
Ornithoptera, 339, 340
Orphnephilidæ, 430
Ortalidæ, 442
Orthezia, *280*, 287
Orthocladius, 422
Orthoptera, 36
Orthorrapha, 398, 415
Orthotylus, 252
Oryctes, *117*, 215
Oryssidæ, 483
Ostomidæ, 138
Oscinella, 447
Oscinis, 447
Oscinidæ, 446
Osmia, 519
Osmylidæ, 303
Osmylus, 111
Osphya, 184
Othniidæ, 179
Otiorhynchus, 206
Ourapteryx, *363*
Oxybelidæ, 514
Oxycarænus, 240
Oxyura, 488

Pachnæus, 206
Pachnephorus, 197
Pachycrepis, 492
Pachyrhina, 416
Pachytylus, 62, 65
Palæococcus, 287
Palæotropinæ, 343
Paleacrita, 364
Palingenia, 26
Palmyra, 360
Pangonia, 432
Panorpa, 11
Panorpidæ, 318
Panurgidæ, 516
Papilio, *339*, 340
Papilionidæ, 339
Papirius, *19*, 20
Parajapyx, 11
Paraneuroptera, 28
Parasa, *377*
Parasemidalis, 300
Parasitica, 478
Parnassius, 340
Parnara, 347
Parnidæ, 156
Passalidæ, 209
Paussidæ, 125
Pectenophora, 393
Pedicinæ, 230
Pediculidæ, 230
Pediculinæ, 230
Pediculus, 227, 229, 230
Pedilidæ, 191
Pegomyia, 453
Pelecinidæ, 488, 490
Pelecinus, 490
Pelobiidæ, 122
Pelobius, 122
Pelogonidæ, 252
Pempheres, 206
Pemphredon, 515
Pemphredonidæ, 514
Pentatoma, 238
Pentatomidæ, 237
Peregrinus, 260
Perilampidæ, 491
Periplaneta, *40*, 45
Peritelus, 206
Perkinsiella, 107, 260
Perla, 22
Perlaria, 21, 289
Perlidæ, 23
Perlodides, 23
Perophora, 376
Perophoridæ, 375
Perothopinæ, 174
Perrisia, 424
Petalurinæ, 29
Petiolata, 478
Petriidæ, 181
Pezomachus, 495
Phædon, 195, 196
Phænocephalidæ, 134
Phalacridæ, 145
Pharsaliinæ, 495
Phasgonura, 71
Phasgonuridæ, 39, 66
Phasmidæ, 39, 51
Phaudinæ, 380
Phenacoleachiinæ, 287
Philanthidæ, 514
Philanthus, 515
Philopotamidæ, 314
Philopteridæ, 102
Phlebotomus, 417
Phleothripidæ, 225
Phlæotribus, 208
Phorbia, 452
Phoridæ, 437
Phorodon, *269*
Phryganea, *314*, *315*
Phryganeidæ, 314
Phryneta, 201
Phthirus, *228*, 230
Phthorimæa, 393
Phycitidæ, 384
Phycitinæ, 384
Phyletinus, 206
Phyllaphis, 275
Phyllium, 51, 52, *53*
Phyllobius, 206
Phyllodromia, 43, 44
Phyllognathus, 215
Phyllopertha, 215
Phyllotreta, 197
Phylloxera, 270, 275
Phylloxerinæ, 275
Phymatidæ, 245
Physapoda, 219
Physopus, 224
Phytalus, 215
Phytonomus, 206
Phytophaga, 193
Phytophthires, 256
Pieridæ, 340
Pieris, *340*, *341*
Pimplinæ, 495
Pionea, *383*
Piophila, 448
Pipunculidæ, 438
Pipunculus, 439
Planipennia, 294
Platygaster, 489
Platygastridæ, 490
Platypezidæ, 438
Platypidæ, 206
Platypsyllidæ, 137
Platyptera, 21
Platypus, 208
Platyrrhinidæ, 202
Platystelea, 12
Plea, 255
Plecoptera, 21
Plectoptera, 24
Plesiocoris, 252
Plusia, 354
Plutellinæ, 394
Plutellidæ, 394
Podops, 238
Podura, 18
Poecilocapsus, 252
Polietes, *457*
Polistes, 511
Pollenia, 455
Pollinia, 287
Polycentropidæ, 314
Polycerata, 127
Polychrosis, 390
Polyctenes, 250
Polyctenidæ, 250
Polymorpha, 127

Polyplocidæ, 359
Polyrhachis, *525*
Polystigmata, 225
Polystœchotidæ, 302
Pompilidæ, 507
Ponerinæ, 525
Prays, 394
Prionus, 201
Prisopus, 54
Proctotrypidæ, 488, 489
Prodenia, 354
Projapygidæ, 9
Projapyx, 9
Promachus, 435
Proscopides, 55
Prosopis, 517, 518
Prosopistoma, 26
Protaptera, 5
Protapteron, 5
Proterhinidæ, 209
Protocalliphora, 454
Protoparce, 358
Protura, 3
Psammocharidæ, 507
Pselaphidæ, 129
Psen, 515
Psenidæ, 513
Psephenidæ, 159
Pseudococcus, *282*
Pseudocorylophidæ, 134
Pseudoneuroptera, 81
Pseudosphinx, 358
Psilidæ, 441
Psilodora, *487*
Psithyrus, 520
Psocoptera, 95
Psocus, 98
Psychidæ, 369
Psychoda, 417
Psychodidæ, 416
Psychomyiidæ, 314
Psychopsidæ, 301
Psychopsis, III, 301
Psylla, 265, *266*, 267
Psyllidæ, 264
Psylliodes, 196
Psyllopa, *265*, 268
Pterochroza, 66
Pterocroce, 310
Pteromalidæ, 491
Pteronarcidæ, 23
Pterophoridæ, 387
Pterostichus, 121
Pterothysanidæ, 354
Pterygota, 21
Ptinidæ, 167
Pulex, 465, 469
Pulicidæ, 468
Pulvinaria, 287
Pupipara, 462
Pyralidæ, 336, 337, 382
Pyralididæ, 386
Pyralidina, 383
Pyralinæ, 386
Pyralis, 387
Pyrameis, 342
Pyraustidæ, 385, 386
Pyraustinæ, 386
Pyrellia, 456
Pyrgotinæ, 442
Pyrilla, *260*
Pyrochroidæ, 189
Pyrophorinæ, 174
Pyrrhocoridæ, 241
Pyrrhocoris, 241
Pythidæ, 183

Ranatra, 253
Raphidia, II
Raphidiidæ, 292
Ratardidæ, 372
Reduviidæ, 246
Rhagoletis, 443, 444
Rhipiceridæ, 161
Rhipiphoridæ, 186
Rhizopertha, 169
Rhodites, 487
Rhogas, 498
Rhopæa, 215
Rhopalocera, 325, 337, 338
Rhopalogastor, 435
Rhopalomeridæ, 445
Rhopalosiphum, 275
Riodinidæ, 345
Ripersia, 287
Rhyacophilidæ, 314
Rhynchites, 205
Rhynchophora, 201
Rhynchophorus, 206
Rhynchota, 232
Rhyphidæ, 430
Rhysodidæ, 126
Rhyssa, 482, 495
Rutelini, 214

Sagrinæ, 194
Saissetia, 287
Salda, 248
Saldidæ, 247
Saltatoria, 38
Sandalus, 161
Sanna, *67*
Sanninoidea, 389
Saperda, 200
Sapromyza, *411*
Sapromyzidæ, 446
Sapygidæ, 505
Sarcophaga, 458
Sarcophagidæ, 457
Sarcopsyllidæ, 468
Sargus, *431*
Saturnia, 334
Saturniidæ, 364
Satyrinæ, 342, 344
Scaphidiidæ, 135
Scapteriscus, 78
Scaptomyza, 447
Scarabæidæ, 213
Scarabæinæ, 214
Scatophaga, *404*, 451
Scelionidæ, 489, 490
Sceliphron, 514
Scenopinidæ, 435
Schistocerca, 60, 63
Schizodactylus, 66, *71*
Schizophora, 440
Schizoneura, 270
Schœnobiinæ, 385
Sciara, 425, 426
Sciomyzidæ, 450
Scirpophaga, 385
Scirtothrips, 224
Scoliidæ, 504
Scolytidæ, 206
Scolytus, 208
Scraptiidæ, 185
Scydmænidæ, 130
Selenophorus, 264
Semasia, 390
Semidalis, 300
Sepsidæ, 448
Sericostomatidæ, 314
Serphidæ, 489, 490
Serphoidea, 488
Serricornia, 159
Sesamia, 353
Sesia, 389
Sesiidæ, 388
Sessiliventres, 478, 480
Sialidæ, 290
Sialis, II
Signiphoridæ, 491
Silpha, 131
Silphidæ, 130
Silvanus, 142
Simuliidæ, 427
Sinodendridæ, 212
Sinoxylon, 169
Siphanta, 260
Siphonaptera, 465
Siphonophora, *270*
Siphonella, 447
Siricidæ, 482
Sisyridæ, 298
Sitaris, 117, 189
Sitones, 206
Sminthuridæ, 19
Sminthurides, 20
Sminthurinus, 20

Sminthurus, 17, 20
Solenopsis, 529
Spalangidæ, 491
Spermophorella, 304
Sphæriidæ, 133
Sphæridiinæ, 158
Sphæritidæ, 138
Sphærocharinæ, 196
Sphecidæ, 514
Sphecoidea, *502*, 513
Sphenoptera, 173
Sphenophorus, 206
Sphindidæ, 170
Sphingidæ, 357
Sphyracephala, 451
Spilosoma, 350
Staphylinidæ, 127
Staphylinoidea, 127
Stauropus, 361, 362
Stegomyia, 419
Steirastoma, 200
Stelididæ, 516
Stelis, 519
Stephanidæ, 499
Stephanitis, 242
Stephanoderes, 208
Stenopelmatus, 71
Stigmodera, 173
Stilbum, 501
Stomoxys, *455*, 456
Stratiomyidæ, 431
Streblidæ, 463
Strepsiptera, 216
Stromatium, 200
Stylopidæ, 216
Stylops, 218
Sylepta, 386
Sympetrum, 29
Symphypleona, 17, 19
Synemon, 378
Synteliidæ, 137
Syntomidæ, 348
Syrphidæ, 439
Syrphus, *408*
Systena, 197

Tabanidæ, 431
Tabanus, *409*, *410*, *432*
Tachardia, 287
Tachinidæ, 458
Tachycines, *70*, 71
Tachytes, 515
Tæniopteryx, 23
Tæniotes, 201
Tæniothrips, *220*, *223*
Tanymecus, 206
Tanypezidæ, 441
Tanypinæ, 422
Telephoridæ, 162
Temnochilidæ, 138
Tenebrio, 177
Tenebrioides, 138
Tenebrionidæ, 176
Tenthredinidæ, 483
Tenthredinoidea, 480
Tenthredo, *484*, 485
Terebrantia, 225
Termes, *83*
Termitidæ, 81
Termitoxenia, 437
Tetrastichidæ, 491
Tetriginæ, 56
Tettigonia, 264
Tettigoniidæ, 66
Tettix, 60
Thais, 339
Thea, 151
Therevidæ, 435
Thermobia, 13
Thoractidæ, 145
Thorybes, *346*
Thripidæ, 225
Thripoctenus, 224
Thrips, 224
Throscidæ, 175
Thyatiridæ, 359
Thynnidæ, 507
Thyrididæ, 382
Thyrsophorus, 95
Thysanoptera, 219
Thysanura, 6
Tineidæ, 394
Tineidæ, 337, 391
Tineina, 392
Tineinæ, 394
Tineola, 394
Tingidæ, 242
Tingis, 242
Tiphia, 504
Tipula, 416
Tipulidæ, 415
Tmetocera, 391
Tomocerus, *18*, 19
Tortricidæ, 336, 337, 389
Tortricina, 389
Trama, 270, 275
Trichobaris, 206
Trichodectes, 102
Trichodectidæ, 102
Trichodes, 165
Trichogrammidæ, 491
Trichomatidæ, 303
Trichophaga, 337, 394
Tricophora, *262*
Trichoptera, 314
Trichopterygidæ, 132
Trichostomes, 195
Tricondylea, 120
Trictenotomidæ, 192
Tridactylinæ, 77
Tridactylus, *77*
Tridymidæ, 491
Trigonalidæ, 499
Trigonidiinæ, 80
Triphleps, 223
Tritoxa, 442
Trixagidæ, 175
Trogoderma, 153
Trogositidæ, 138
Trypetidæ, 443
Trypodendron, 208
Trypoxylon, 515
Trypoxylonidæ, 514
Tryxalis, *56*
Tubulifera, 225
Tubulifera, 500
Typhlocyba, 264

Ulidiinæ, 442
Ulocerinæ, 201
Uracanthus, 200
Uraniidæ, 368
Urothripidæ, 225

Vanessa, *342*, 343
Vermileo, 431
Vespa, 511, 512
Vespidæ, 510
Vespoidea, 501
Vipionidæ, 496
Virachola, 345
Volucella, 440

Walkeriana, 287

Xenopsylla, *465*, 469
Xenos, *217*, 218
Xestobium, 168
Xiphidium, 68
Xiphydria, 482
Xiphydriidæ, 483
Xyleborus, 208
Xylocopa, 520
Xylocopidæ, 516
Xylocrius, 201
Xylopertha, 169
Xylophilidæ, 190
Xylotrechus, 200
Xylotrupes, 215

Zabrus, 121
Zelotypia, 395
Zephyrus, *344*, 345
Zeuzera, 373
Zicrona, *237*
Zoraptera, 92
Zorotypidæ, 94
Zorotypus, 93, 94
Zygænidæ, 379
Zygoptera, 29, 31

INDEX TO ENGLISH NAMES

All English names of insects are here indexed separately, but only with reference to their mention in their systematic position: there are a few topical references, but no attempt to index subjects mentioned, authors or publications.

Alder-flies, 289, 290
Ant-lions, 310
Ants, 523
Apple Span Worm, 364
Apple Sucker, 265
Argentine Ant, 527, 528
Army worms, 336, 352
Assassin-flies, 434

Bag worms, 369
Bark Borers, 206
Bed-bugs, 249
Bees, 515
Bird Lice, 99
Biting Lice, 99
Black Arches, 356
Blackbeetles, 39
Black onion-fly, 442
Blow-flies, 455
Bluebottles, 453
Body Louse, 230
Bollworms, 336, 351, 353, 363
Book Lice, 95
Borers, 336, 353, 384
Bot-flies, 461
Breeze-flies, 431
Bristletails, 11
Brown lace-wings, 296
Brown tail, 356
Buffalo-gnats, 427
Buff Ermine, 350
Bugs, 232
Bumble-bees, 520
Burnets, 379
Burying Beetles, 130

Cabbage-root fly, 45
Cabbage White, 340
Caddis-flies, 314
Canker Worms, 364
Carpenter-bees, 520
Carrot-fly, 441
Case weavers, 369
Celery-fly, 443
Cellar Beetle, 177
Cheese-hoppers, 448
Chigoes, 468
Clegs, 431
Click Beetles, 173
Clothes moth, 337, 394
Clouded Border, *363*
Cluster fly, 455
Cochineal, 286
Cockroaches, 39
Codlin Moth, 337, 390
Colorado Beetle, 195
Congo floor maggot, 454
Cotton-stainers, 241
Crab Louse, 230
Crane-flies, 415
Crickets, 72
Cuckoo-spit, 261
Cutworms, 336, 352

Daddy-long-legs, 415
Death Watches, 95
Demoiselles, 31
Diamond Back moth, 394
Digger-wasps, 504, 507, 513
Dragonflies, 28
Drinker Moth, *356*

Earwigs, 103
European Corn Borer, 356
Eye-fly, 447

Fig-insect, 493
Fire-brat, 13
Fire-flies, 174
Flea-beetles, 195
Fleas, 465, 468
Flesh-flies, 457
Flies, 397
Flour moth, 337, 384
Fluted Scale, 286
Footmen, 349
Forest-fly, 462
Fringewings, 219
Frit-fly, 447
Froghoppers, 261
Frog-spit, 261
Fruit borers, 337, 390
Fruit flies, 443
Fungus gnats, 425

Gad-flies, 431
Gall gnats, 423
Gall wasps, 486
Gipsy moth, 356
Gnats, 418
Goat moth, 372
Golden Eyes, 304
Gout-fly, 447
Grass moths, 384
Greenbottles, 453
Greenfly, 268
Grasshoppers, 54
Green Grasshoppers, 66
Green lace-wings, 304

Hawk moths, 357
Head Louse, 230
Hessian fly, 423, 424
Hive-bees, 520
Honey-bees, 520
Hook-tips, 381
Hornet, 512
Horse-flies, 431
Horse-stingers, 28
House-fly, 453, 454
Hover-flies, 439
Humming Bird moths, 357, 358

Ichneumon flies, 494

Jerusalem Cricket, 71
Jiggers, 468

Jumpers, 448
Jumping Plant-lice, 264

Katydid, 68, *69*
Kentish Glory, 374

Lac, 286
Lace-wings, 294
Lace-wing Bugs, 242
Lackey, 374
Ladybirds, 150
Leaf-curling midge, 424
Leaf-cutting bees, 519
Leaf-footed Bugs, 238
Leaf hoppers, 263
Leaf Insects, 51
Leather-jacket, 415
Lepidoptera, colours of, 329
Lepidoptera, larvæ of, 323
Lesser House-fly, 452
Lice, 226
Lobster moth, 361
Locust, 39, 54
Longicorns, 197
Longhorn Grasshoppers, 55, 66
Loopers, 363

Mason-bees, 519
Mayflies, 24
Meal worm, 177
Mealybugs, 279
Mealy Wings, 276
Mediterranean fruit-fly, 443, 445
Midges, 421
Mole Cricket, 77
Mosquitos, 418
Moth-flies, 416
Moth lace-wings, 29
Mud-wasps, 509
Musk Beetle, 199

Onion-fly, 452
Orange Tip, 341
Owlet-moths, 350
Owl-midges, 416

Peach Scale, 286
Pill Beetles, 153
Pink Bollworm, 393
Plant-lice, 268
Plume moths, 387
Praying Mantises, 45
Prominents, 360
Pubic Louse, 230
Pulse Beetles, 193
Puss Moth, *361*

Rat-tailed maggot, 440
Red Ant, 527
Red Slug caterpillars, 380
Rice Case Worm, 385
Robber-flies, 434
Rove Beetles, 127
Ruby-wasps, 500

Sand Cricket, 71
Sand-flies, 416
San José Scale, 286
Saw-flies, 483
Scale Insects, 279
Screw-worm fly, 454
Sheep-ked, 462
Sheep-maggot fly, 455
Sheep-tick, 462
Shield Bugs, 237
Shorthorn Grasshoppers, 55
Signal-flies, 442
Silk, 331
Silk, Chinese Tussar, 335
Silk, Eri, 331, 334
Silk, Muga, 331, 335
Silk, Mulberry, 331, 332, 367
Silk, Shantung, 332, 335
Silk, Tussar, 331, 334, *365*
Silver-fish, 13
Skippers, 346
Snake-flies, 289
Soothsayers, 45
Span-worms, 363
Squeaker, 122
Stag-beetle, 212
Stem Saw-flies, 480
Stick Insects, 51
Stink-flies, 304
Sucking Lice, 226
Sulphurs, 340
Surface Caterpillars, 336, 351, 352
Swallowtails, 339
Swifts, 395

Tent caterpillars, 374
Termites, 81
Thorn Insects, 260
Thrips, 219
Tiger-beetles, 119
Tiger Moths, 349
Tsetse flies, 456
Tussock moths, 354

Vapourer moth, *355*

Warble-flies, 461
Wasps, 510
Waterscorpion, 253
Weevils, 203
Western Cricket, 71
Western Grain Saw-fly, 481
Wheat bulb fly, 453
Wheat joint worm, 492
Wheat midge, 425
Whirligigs, 124
Whites, 340
White Ants, 81
White Fly, 276
Wild silk moths, 364
Window-flies, 435
Wire-worms, 174
Wood Ant, 527
Wood-borers, 482
Wood-wasps, 482

A SELECTION OF

Messrs. Edward Arnold & Co.'s Scientific & Technical Publications

PHYSICS

GENERAL ASTRONOMY. By H. Spencer Jones, M.A., Sc.D., H.M. Astronomer at the Cape. viii + 392 pages, with 102 diagrams and 24 plates. Third Impression. Demy 8vo, 21s. net.

THE LIFE OF LORD RAYLEIGH. By his son, Robert John Strutt, Fourth Baron Rayleigh, F.R.S. Demy 8vo, xii +403 pages. 25s. net.

ISOTOPES. By F. W. Aston, Sc.D., D.Sc., F.R.S., Nobel Laureate, Fellow of Trinity College, Cambridge. viii + 182 pages, with diagrams and plates. Second Edition. Demy 8vo, 10s. 6d. net.

IONS, ELECTRONS, AND IONIZING RADIATIONS. By J. A. Crowther, M.A., Sc.D., Professor of Physics at the University of Reading. Fifth Edition. Thoroughly revised. xii +353 pages. Demy 8vo, 12s. 6d. net.

THE DYNAMICAL THEORY OF SOUND. By Horace Lamb, Sc.D., F.R.S., Rayleigh Lecturer in the University of Cambridge. Second Edition. viii + 307 pages. Demy 8vo, 18s. net.

SOUND. A Physical Textbook. By E. G. Richardson, M.Sc., Ph.D., Assistant Lecturer in the Physics Department, University College, London. viii +286 pages, with 86 illustrations. Demy 8vo, 15s. net.

THE ACOUSTICS OF ORCHESTRAL INSTRUMENTS AND OF THE ORGAN. By E. G. Richardson, M.Sc., Ph.D. Demy 8vo, 160 pages, with 20 plates, 10s. 6d. net.

AN INTRODUCTION TO THE THEORY OF OPTICS. By Sir Arthur Schuster, Sc.D., F.R.S. Third Edition. Revised by the Author and J. W. Nicholson, D.Sc., F.R.S., Fellow and Tutor of Balliol College, Oxford. xvi +405 pages, 188 illustrations. Demy 8vo, 18s. net.

LECTURE EXPERIMENTS IN OPTICS. By B. K. Johnson. 112 pages, with 87 diagrams. Demy 8vo.

COLOUR VISION. A Discussion of the Leading Phenomena and their Physical Laws. By W. Peddie, D.Sc., F.R.S.E., Harris Professor of Physics at University College, Dundee. xii + 208 pages. Demy 8vo, 12s. 6d. net.

MOLECULAR MAGNETISM. By W. Peddie, D.Sc., F.R.S.E. Demy 8vo. viii + 140 pages, with 38 diagrams. 10s. net.

AERONAUTICS IN THEORY AND EXPERIMENT. By W. L. Cowley, A.R.C.S., D.I.C., and H. Levy, M.A., D.Sc., F.R.S.E. Second Edition. xii + 332 pages. Demy 8vo, 25s. net.

A TEXT-BOOK OF PHYSICS. By R. S. Willows, M.A. (Camb.), D.Sc. (London). Third Edition. viii + 520 pages, with 320 diagrams. Large crown 8vo, 9s.

THE PRINCIPLES OF PHYSICS. A Textbook for Students of Pharmacy. By C. J. Smith, Ph.D., D.I.C. Crown 8vo. viii + 288. pages 9s.

AN INTRODUCTION TO FLUID MOTION. By W. N. Bond, D.Sc., F.Inst.P., Lecturer in Physics at the University of Reading. Crown 8vo. 5s. net.

HEAT. By W. J. R. CALVERT, M.A., Harrow School. viii + 344 pages, with 138 diagrams. Crown 8vo, 6s.

LIGHT. By F. BRAY, M.A., late Science Master at Clifton College. xvi + 284 pages, with 234 diagrams and 6 plates. Crown 8vo, cloth, 6s.

ELECTRICITY AND MAGNETISM. By C. E. ASHFORD, M.A., Headmaster of the Royal Naval College, Dartmouth. With over 200 diagrams. THIRD REVISED EDITION. Crown 8vo, 4s. 6d.

MATHEMATICS

FIVE-FIGURE TABLES OF MATHEMATICAL FUNCTIONS. By J. B. DALE, M.A., Assistant Professor of Mathematics at King's College, London. Demy 8vo, 4s. 6d. net.

LOGARITHMIC AND TRIGONOMETRIC TABLES (To Five Places of Decimals). By J. B. DALE, M.A. Demy 8vo, 2s. 6d. net.

THE CALCULUS FOR ENGINEERS. By JOHN PERRY, M.E., D.Sc., F.R.S. THIRTEENTH IMPRESSION. viii + 382 pages. Crown 8vo, 8s. 6d.

CALCULUS FOR TECHNICAL STUDENTS. By S. N. FORREST, M.A., B.Sc. Crown 8vo, viii + 231 pages, 5s.

CALCULUS FOR SCHOOLS. By R. C. FAWDRY, M.A., Head of the Military and Engineering Side at Clifton College; and C. V. DURELL, Senior Mathematical Master at Winchester College. Crown 8vo. With Answers. In one volume, 6s. 6d. Part I, 3s. 6d.; Part II, 4s.

AN INTRODUCTION TO PROJECTIVE GEOMETRY. By L. N. G. FILON, M.A., D.Sc., F.R.S., Professor of Applied Mechanics, University College, University of London. THIRD EDITION. viii + 261 pages. Crown 8vo, 7s. 6d.

HIGHER ALGEBRA. By W. P. MILNE, M.A., D.Sc., Professor of Mathematics in the University of Leeds. xii + 586 pages. Crown 8vo, 8s. 6d.

HOMOGENEOUS CO-ORDINATES. By W. P. MILNE, M.A., D.Sc. xii + 164 pages. Crown 8vo, 6s. net.

ENGINEERING

BRITISH ENGINEERING WAGES. By R. SPICER. Demy 8vo. 160 pages. 10s. 6d. net.

THE STRENGTH OF MATERIALS. A Treatise on the Theory of Stress Calculations for Engineers. By J. CASE, M.A., F.R.Ae.S., Lecturer in Applied Mechanics at the Royal Naval Engineering College, Keyham Med. 8vo. viii + 558 pages. 30s. net.

STRENGTH AND STRUCTURE OF STEEL AND OTHER METALS. By W. E. DALBY, F.R.S., M.A., B.Sc., M.Inst.C.E., M.I.M.E., University Professor of Engineering at the City and Guilds (Engineering) College. Very fully illustrated. 192 pages and 38 plates. Medium 8vo, 18s. net.

STEAM POWER. By Professor W. E. DALBY, F.R.S., M.Inst.C.E., M.I.M.E. SECOND EDITION. xvi + 760 pages, with 250 diagrams. 8vo, 25s. net.

VALVES AND VALVE GEAR MECHANISMS. By Professor W. E. DALBY, F.R.S. xviii + 366 pages, 202 illustrations. Royal 8vo, 24s. net.

THE BALANCING OF ENGINES. By Professor W. E. DALBY, F.R.S. FOURTH EDITION. xii + 321 pages, 218 illustrations. Medium 8vo, 21s. net.

PROPERTIES OF STEAM AND THERMODYNAMIC THEORY OF TURBINES. By H. L. CALLENDAR, F.R.S., Professor of Physics in the Imperial College of Science and Technology. 544 pages, numerous diagrams. 8vo, 30s. net.

THE ENLARGED CALLENDAR STEAM TABLES. (Fahrenheit Units.) 7s. 6d. net.

THE CALLENDAR STEAM TABLES. 3s. 6d. net.

ABRIDGED CALLENDAR STEAM TABLES. (Centigrade Units.) SECOND EDITION. 8vo, 1s. net.

ABRIDGED CALLENDAR STEAM TABLES. (Fahrenheit Units.) SECOND EDITION. 8vo, 1s. net.

THE MOLLIER DIAGRAM. Drawn by Professor CALLENDAR and printed on green squared paper. 1s. net.

THE ENLARGED MOLLIER DIAGRAM. Drawn by Professor CALLENDAR. Printed in three colours on squared paper. 4s. net.

THE CALLENDAR STEAM DIAGRAM. (Centigrade Units.) 6d. net.

THE CALLENDAR STEAM DIAGRAM. (Fahrenheit Units.) 6d. net.

HEAT DROP TABLES: ABSOLUTE PRESSURES. Calculated by H. Moss, M.Sc., A.R.C.S., from the Formulæ and Steam Tables of Professor H. L. Callendar, F.R.S. 64 pages. Cloth, 5s. net.

HEAT DROP TABLES: H.P. GAUGE PRESSURES, L.P. ABSOLUTE PRESSURES. Calculated by H. Moss, Imperial College of Science, from Professor Callendar's Formulæ and Steam Tables. Cloth, 5s. net.

THE ENLARGED HEAT DROP TABLES: H.P. GAUGE PRESSURES, L.P. ABSOLUTE PRESSURES. 10s. 6d. net.

CORRECTION TABLES FOR THERMODYNAMIC EFFICIENCY. Calculated by C. H. NAYLOR, Assoc.M.Inst.C.E. Cloth, 5s. net.

ELECTRICAL SUBSTATIONS. By H. BRAZIL, M.I.E.E. 224 pages, with 56 illustrations. Demy 8vo, 12s. 6d. net.

RAILWAY ELECTRIC TRACTION. By F. W. CARTER, Sc.D., M.I.E.E., M.Inst.C.E., British Thomson-Houston Co., Rugby. viii + 412 pages, with 204 illustrations and 10 folding plates. Demy 8vo, 25s. net.

ELECTRIC TRAINS. By R. E. DICKINSON, B.Sc., A.M.I.E.E. xii + 292 pages, with 139 diagrams. Demy 8vo, 16s. net.

THE PRACTICE OF RAILWAY SURVEYING AND PERMANENT WAY WORK. By S. WRIGHT PERROTT, M.A.I., M.Inst.C.E., and F. E. G. BADGER, A.M.Inst.C.E. viii + 304 pages, with 140 diagrams. Demy 8vo, 30s. net.

THE ECONOMICS OF RAIL TRANSPORT IN GREAT BRITAIN. By C. E. R. SHERRINGTON, M.A., A.M.Inst.T., London School of Economics. Vol. I, History and Development. Vol. II, Rates and Service. Demy 8vo, 12s. 6d. net each volume.

THE MEASUREMENT OF FLUID VELOCITY AND PRESSURE. By the late J. R. PANNELL. Edited by R. A. FRAZER, B.A., B.Sc., National Physical Laboratory. viii + 138 pages. 10s. 6d. net.

HYDRAULICS. For Engineers and Engineering Students. By F. C. LEA, D.Sc., M.Inst.C.E., Professor of Mechanical Engineering in the University of Sheffield. FIFTH EDITION. About 750 pages and 550 diagrams. Demy 8vo.

ELEMENTARY HYDRAULICS. For Technical Students. By F. C. LEA, D.Sc., M.Inst.C.E. viii + 224 pages, with 156 diagrams. Crown 8vo, 7s. 6d.

MODERN METHODS OF WATER PURIFICATION. By JOHN DON, F.I.C., A.M.I.Mech.E., and JOHN CHISHOLM, A.M.I.Mech.E. SECOND EDITION. xviii + 398 pages, 106 illustrations. Demy 8vo, 16s. net.

REINFORCED CONCRETE DESIGN. VOL. I.: THEORY. By OSCAR FABER, D.Sc., M.Inst.C.E., and P. G. BOWIE, A.M.Inst.C.E. xx + 332 pages, 158 diagrams. SECOND EDITION. Demy 8vo, 14s. net. VOL. II.: PRACTICE. By OSCAR FABER, D.Sc., M.Inst.C.E. xii + 246 pages, 89 diagrams. Demy 8vo, 18s. net.

MODERN ROADS. By H. P. Boulnois, M.Inst.C.E., F.R.San.Inst., etc. xii + 302 pages. Demy 8vo, 16s. net.

SURVEYING. By Professor W. N. Thomas, M.Sc. (Birmingham), B.Sc. Eng. (London), Assoc.M.Inst.C.E., A.M.I.Mech.E., A.M.Inst. M. and Cy.E. Second Edition. viii + 536 pages and 298 diagrams. 8vo, 25s. net.

THE FIELD ENGINEER'S HANDBOOK. By G. C. Wells and A. S. Clay, B.Sc. Second Edition. Small 8vo, 8s. 6d. net.

TRAVERSE TABLES. By Henry Louis, M.A., D.Sc., M.I.C.E., and G. W. Caunt, M.A. Second Edition. 8vo, 5s. 6d. net.

TACHEOMETER TABLES. By H. Louis, M.A., D.Sc., M.I.C.E., and G. W. Caunt, M.A. 8vo, 10s. 6d. net.

A TEXT-BOOK OF ELECTRICAL ENGINEERING. By Dr. A. Thomälen. Translated by Professor G. W. O. Howe, D.Sc. Fourth Edition. xii + 482 pages, 480 diagrams. Demy 8vo, 28s. net.

THE PRINCIPLES OF ELECTRICAL ENGINEERING AND THEIR APPLICATION. By Dr. G. Kapp. Volume I.: Principles. xii + 356 pages. Demy 8vo, 18s. net. Volume II.: Application. x + 388 pages. 18s. net.

THE THEORY OF MACHINES. By R. F. McKay, M.Sc., A.M.Inst. C.E. Second Edition. viii + 440 pages, 407 diagrams. Demy 8vo, 20s. net.

GRINDING MACHINERY. By J. J. Guest, M.A., M.I.Mech.E. xii + 444 pages, with illustrations. Demy 8vo, 16s. net.

METAL WORK. By H. M. Adam and J. H. Evans. Second Edition. 277 pages, with 217 illustrations. Crown 8vo. Cloth, 6s. 6d.

THE STRENGTH AND ELASTICITY OF STRUCTURAL MEMBERS. By R. J. Woods, M.E., M.Inst.C.E. Second Edition. xii + 310 pages, 292 illustrations. Demy 8vo, 14s. net.

EXAMPLES IN THE STRENGTH AND ELASTICITY OF MATERIALS. By G. W. Bird, B.Sc. Crown 8vo. 10s. 6d. net.

THE THEORY OF STRUCTURES. By R. J. Woods, M.E., M.Inst. C.E. xii + 270 pages, 157 illustrations. Demy 8vo, 12s. 6d. net.

THE ITALIAN ORDERS OF ARCHITECTURE. By Charles Gourlay, B.Sc., A.R.I.B.A. Large 4to. Second Edition. 8s. net.

AN INTRODUCTION TO BUILDING SCIENCE. By F. L. Brady, M.Sc., A.I.C. Crown 8vo, viii + 280 pages, with 63 illustrations. 7s. 6d.

MECHANICAL DRAWING. With Special Reference to the Needs of Mining Students. By Joseph Husband, B.Eng., A.M.I.C.E., Professor of Civil Engineering at Sheffield University. With 40 plates. Quarto, 3s. 6d.

MACHINE SKETCHES AND DESIGNS. By Professor A. Cruickshank, M.I.Mech.E., and R. F. McKay, M.Sc., A.M.Inst.C.E. Third Edition. Quarto, 2s. 6d.

FIRST YEAR ELECTRICAL ENGINEERING. By D. J. Bolton, M.Sc., M.I.E.E., Lecturer at the Polytechnic, London. xii + 260 pages, with 118 diagrams. Crown 8vo, 5s.

EXAMPLES IN ELECTRICAL ENGINEERING. By J. F. Gill, M.Sc., B.Eng., A.M.I.Mech.E.; and Professor F. J. Teago, D.Sc., M.I.E.E., The University, Liverpool. Second Edition. Crown 8vo, 7s. 6d. net.

GEOLOGY AND MINING

THE GEOLOGY OF THE BRITISH EMPIRE. By F. R. C. Reed, Sc.D., F.G.S. viii + 480 pages, with 25 maps and sections. Demy 8vo, 30s. net.

THE STRUCTURE OF THE ALPS. By L. W. Collet, D.Sc. xii + 282 pages, with 63 figures and 12 plates. Demy 8vo, 16s. net.

STRUCTURE AND SURFACE. A Book of Field Geology. By C. Barrington Brown, M.A, F.G.S., and F. Debenham, M.A., F.G.S. viii + 168 pages, with 104 illustrations. Medium 8vo, 10s. 6d. net.

PHYSICO-CHEMICAL GEOLOGY. By R. H. Rastall, Sc.D., Lecturer in Economic Geology in the University of Cambridge. viii + 48 pages, with 62 diagrams. 15s. net.

OIL FINDING: An Introduction to the Geological Study of Petroleum. By E. H. Cunningham Craig, B.A., F.G.S. Second Edition. xii + 324 pages, 13 plates and 20 illustrations. Demy 8vo, cloth, 16s. net.

THE DRESSING OF MINERALS. By H. Louis, D.Sc., M.I.M.E., M.Inst.C.E. x + 544 pages, 416 illustrations. Super royal 8vo, cloth, 30s. net.

COAL IN GREAT BRITAIN. By Walcot Gibson, D.Sc., F.G.S., F.R.S.E. Second Edition. viii + 312 pages, with 50 diagrams and 8 plates. Demy 8vo, 21s. net.

COAL MEASURE PLANTS. By R. Crookall, Ph.D., of the Geological Survey of Great Britain. Medium 8vo, with 40 plates. 12s. 6d. net.

THE ECONOMICS OF COAL MINING. By R. W. Dron, M.A., F.R.S.E., Professor of Mining in the University of Glasgow. viii + 168 pages, with 13 figures and 26 tables. Demy 8vo, 10s. 6d. net.

MINING SUBSIDENCE. By Henry Briggs, C.B.E., D.Sc., Professor of Mining in the University of Edinburgh. Demy 8vo. viii + 216 pages. 14s. net.

WINDING ENGINES AND WINDING APPLIANCES: Their Design and Economical Working. By G. McCulloch, A.M.I.M.E., and T. C. Futers, M.Inst.M.E. viii + 452 pages, 175 illustrations. Demy 8vo, 21s. net.

A TEXTBOOK OF GEOLOGY. By P. Lake, M.A., F.G.S., and R. H. Rastall, Sc.D., F.G.S. xiv + 508 pages, fully illustrated. Fourth Edition. Demy 8vo, 21s. net.

OUTLINES OF PALÆONTOLOGY. By H. H. Swinnerton, D.Sc., F.G.S. xii + 420 pages, with 368 diagrams. Demy 8vo, cloth, 30s. net.

THE PHYSIOGRAPHICAL EVOLUTION OF BRITAIN. By L. J. Wills, Sc.D., F.G.S., Lecturer in Geology in the University of Birmingham. viii + 368 pages, with 154 diagrams and 3 folding maps. Demy 8vo, 21s. net.

A STUDY OF THE OCEANS. By James Johnstone, D.Sc. Second Edition. viii + 235 pages, with 44 illustrations. Demy 8vo. 10s. 6d. net.

THE GEOLOGY OF ORE DEPOSITS. By H. H. Thomas, M.A., B.Sc., and D. A. MacAlister, A.R.S.M. Crown 8vo, 8s. 6d. net.

THE GEOLOGY OF BUILDING STONES. By J. Allen Howe, B.Sc. viii + 455 pages, fully illustrated. Crown 8vo, 8s. 6d. net.

THE GEOLOGY OF SOILS AND SUBSTRATA. By the late H. B. Woodward, F.R.S. xvi + 366 pages, with illustrations. Crown 8vo, 8s. 6d. net.

GEOLOGICAL AND TOPOGRAPHICAL MAPS: Their Interpretation and Use. By A. R. Dwerryhouse, D.Sc., F.G.S. Second Edition. viii + 133 pages, with 90 illustrations. Demy 8vo, 6s. net.

THEORY AND PRACTICE OF MINE VENTILATION. By T. Bryson, M.I.Min.E. viii + 255 pages, with 81 illustrations. Crown 8vo., 8s. 6d.

CHEMISTRY AND METALLURGY

THE DISCOVERY OF THE RARE GASES. By MORRIS W. TRAVERS, D.Sc., F.R.S. viii + 128 pages, with facsimile reproductions from Sir William Ramsay's Notebooks. Demy 4to, 15s. net.

THE ORDINALL OF ALCHIMY. Written by THOMAS NORTON of Bristoll. Facsimile Reproduction from *Theatrum Chemicum Britannicum.* viii + 125 pages. Demy 8vo, 10s. 6d. net.

AN ETYMOLOGICAL DICTIONARY OF CHEMISTRY AND MINERALOGY. By DOROTHY BAILEY, B.Sc., Ph.D., and KENNETH C. BAILEY, M.A., Sc.D. xii + 292 pages. Demy 8vo, 25s. net.

THE ELDER PLINY'S CHAPTERS ON CHEMICAL SUBJECTS. Translated with a critical commentary by KENNETH C. BAILEY, M.A., Sc.D. 249 pages. Royal 8vo, 12s. 6d. net.

METALS AND METALLIC COMPOUNDS. By U. R. EVANS, M.A., King's College, Cambridge. 4 vols., obtainable separately. Demy 8vo. Vol. I., 21s. net. Vol. II., 18s. net. Vol. III., 14s. net. Vol. IV., 18s. net.

THE CORROSION OF METALS. By U. R. EVANS, M.A. SECOND EDITION. Demy 8vo. xvi+259 pages. 15s. net.

A BIBLIOGRAPHY OF METALLIC CORROSION. By W. H. J. VERNON, D.Sc., F.I.C. xii + 341 pages. Demy 8vo, 21s. net.

SERVICE CHEMISTRY. By the late VIVIAN B. LEWES, F.I.C., F.C.S.; and J. S. S. BRAME, C.B.E., F.I.C., Professor of Chemistry, Royal Naval College, Greenwich. FIFTH EDITION. xvi + 576 pages. Illustrated. Demy 8vo, 21s.

FUEL. Solid, Liquid, and Gaseous. By J. S. S. BRAME, C.B.E. THIRD EDITION. xvi + 388 pages, 73 diagrams. Demy 8vo, 18s. net.

PETROL AND PETROLEUM SPIRITS. A Description of their Sources, Preparation, Examination, and Uses. By W. E. GOODAY, A.R.S.M., D.I.C., A.M.Inst.P.T. xii + 135 pages. Demy 8vo, 10s. 6d. net.

THE ABSORPTION OF NITROUS GASES. By H. W. WEBB, M.Sc., F.I.C. Demy 8vo, 25s. net.

THE RARE EARTHS: Their Occurrence, Chemistry and Technology. By S. I. LEVY, M.A., F.I.C. xvi+362 pages. Demy 8vo, 18s. net.

THE CHEMISTRY AND MANUFACTURE OF HYDROGEN. By P. LITHERLAND TEED, A.R.S.M. Illustrated. Demy 8vo, cloth, 10s. 6d. net.

THE PRINCIPLES OF APPLIED ELECTRO-CHEMISTRY. By A. J. ALLMAND, D.Sc., Professor of Chemistry, King's College, London, and H. J. T. ELLINGHAM, B.Sc. SECOND EDITION. Medium 8vo. xii+727 pages and 171 diagrams. 35s. net.

ANTIQUES: Their Restoration and Preservation. By A. LUCAS, F.I.C. Crown 8vo, 6s. net.

ANCIENT EGYPTIAN MATERIALS. By A. LUCAS, F.I.C. Crown 8vo, 7s. 6d. net.

AN INTRODUCTION TO ORGANIC CHEMISTRY. By E. J. HOLMYARD, D.Litt., F.I.C. viii + 282 pages. Crown 8vo. 4s. 6d.

OUTLINES OF ORGANIC CHEMISTRY. By E. J. HOLMYARD, D.Litt., F.I.C. viii + 456 pages. Crown 8vo, 7s. 6d.

ORGANIC CHEMISTRY FOR ADVANCED STUDENTS. By JULIUS B. COHEN, Ph.D., D.Sc., F.R.S. FIFTH EDITION, in Three Parts, obtainable separately. Demy 8vo, 18s. net each part.

THE CONSTITUTION OF SUGARS. By W. N. HAWORTH, D.Sc. F.R.S., Professor of Chemistry in the University of Birmingham. viii + 100 pages with 2 plates. Medium 8vo, 8s. 6d. net.

BIO-CHEMISTRY. A Study of the Origin, Reactions, and Equilibria of Living Matter. By the late BENJAMIN MOORE, M.A., D.Sc., F.R.S. viii + 340 pages. Demy 8vo, 21s. net.

CHEMICAL DISINFECTION AND STERILIZATION. By S. RIDEAL, D.Sc., F.I.C., and E. K. RIDEAL, M.A., D.Sc., F.I.C. 321 pages. Demy 8vo, 21s. net.

SMOKE. A Study of Town Air. By Prof. J. B. COHEN, F.R.S., and Dr. A. G. RUSHTON. SECOND EDITION, with 15 plates. Demy 8vo, 8s. 6d. net.

THE EVOLUTION AND DEVELOPMENT OF THE QUANTUM THEORY. By N. M. BLIGH, A.R.C.S. Demy 8vo, 9s. net.

THE PROBLEM OF PHYSICO-CHEMICAL PERIODICITY. By E. S. HEDGES, Ph.D., and J. E. MYERS, O.B.E., D.Sc. Demy 8vo, 7s. 6d. net.

PHYSICAL CHEMISTRY: its Bearing on Biology and Medicine. By J. C. PHILIP, D.Sc., F.R.S., Professor of Physical Chemistry in the Imperial College of Science and Technology. THIRD EDITION. Crown 8vo, 8s. 6d. net.

ELEMENTARY PHYSICAL CHEMISTRY. By W. H. BARRETT, M.A., Harrow School. viii + 247 pages, with 61 diagrams. 6s.

THE CHEMISTRY OF COLLOIDS and some Technical Applications. By W. W. TAYLOR, M.A., D.Sc., Lecturer in Chemical Physiology in the University of Edinburgh. SECOND EDITION. Crown 8vo, 10s. 6d. net.

PRACTICAL PHOTOMICROGRAPHY. By J. E. BARNARD, F.R.S., and F. V. WELCH, F.R.M.S. SECOND EDITION. xii + 316 pages, with 87 illustrations and 16 plates. Demy 8vo. Cloth, 18s. net.

ANALYTICAL MICROSCOPY. By T. E. WALLIS, B.Sc., Reader in Pharmacognosy in London University. viii + 150 pages. Illustrated. Crown 8vo, cloth, 6s. net.

AN INORGANIC CHEMISTRY. By H. G. DENHAM, M.A., D.Sc., Ph.D., Professor of Chemistry in the University of New Zealand. xii + 688 pages, with 144 diagrams. SECOND EDITION. Crown 8vo, 12s. 6d. net.

INORGANIC CHEMISTRY. A Textbook for Colleges and Schools. By E. J. HOLMYARD, D.Litt., Head of the Science Department, Clifton College. viii + 564 pages, with 119 diagrams and 10 plates. Crown 8vo, 6s. 6d.

ANALYTICAL PROCESSES: A Physico-Chemical Interpretation. By T. B. SMITH, B.Sc., A.R.C.S., The University, Sheffield. viii + 373 pages, with 51 diagrams. Demy 8vo, 12s. 6d. net.

INTERMEDIATE PRACTICAL CHEMISTRY. By E. S. HEDGES, D.Sc., Bedford College, University of London. 128 pages. Demy 8vo, 5s.

A HANDBOOK OF ORGANIC ANALYSIS: QUALITATIVE AND QUANTITATIVE. By H. T. CLARKE, B.Sc., A.I.C. xvi + 363 pages. FOURTH EDITION. Crown 8vo, 8s. 6d. net.

AN ELEMENTARY CHEMISTRY. By E. J. HOLMYARD, D.Litt. viii + 430 pages. SECOND EDITION. Crown 8vo, 5s.

FIRST AID IN THE LABORATORY AND WORKSHOP. By A. A. ELDRIDGE, B.Sc., and H. V. A. BRISCOE, D.Sc. Cloth, 1s. 3d. net.

BIOLOGY

FOUNDERS OF OCEANOGRAPHY AND THEIR WORK. By Sir WILLIAM HERDMAN, C.B.E., F.R.S. xii + 340 pages, 29 plates. Demy 8vo, 21s. net.

MANUAL OF ENTOMOLOGY. By the late H. MAXWELL LEFROY, M.A. xvi + 552 pages. Fully illustrated. Demy 8vo, 35s. net.

BRITISH HYMENOPTERA. By A. S. BUCKHURST, D.I.C., L. N. STANILAND, D.I.C., and G. B. WATSON, D.I.C. Crown 4to, 9s. net.

AN INTRODUCTION TO PHYSICAL ANTHROPOLOGY. By E. P. STIBBE, F.R.C.S. viii + 200 pages, with 42 diagrams and 1 coloured map. Demy 8vo. 12s. 6d. net.

MAN'S PLACE AMONG THE MAMMALS. By F. WOOD JONES, F.R.S., Demy 8vo. viii + 376 pages, with 170 illustrations 21s. net.

THE ANIMAL MIND. By C. LLOYD MORGAN, D.Sc., F.R.S. Demy 8vo.

THE MECHANISM OF LIFE. In Relation to Modern Physical Theory. By J. JOHNSTONE, D.Sc. xii + 248 pages, with 53 diagrams. Demy 8vo, 15s. net.

THE PROGRESS OF LIFE. A Study in Psychogenetic Evolution. By ALEXANDER MEEK, D.Sc. viii + 193 pages, with illustrations. Demy 8vo. 10s. 6d. net.

THE MIGRATIONS OF FISH. By ALEXANDER MEEK, D.Sc. With illustrations and maps. xx + 428 pages. Demy 8vo, 18s. net.

AN INTRODUCTION TO THE SCIENTIFIC STUDY OF THE SOIL. By N. M. COMBER, D.Sc. Crown 8vo, 192 pages, 7s. 6d. net.

THE SCIENTIFIC PRINCIPLES OF PLANT PROTECTION. By HUBERT MARTIN, M.Sc. xii + 310 pages. Demy 8vo, 21s. net.

ANIMAL LIFE IN DESERTS. By P. A. BUXTON, M.A. xvi + 172 pages, with 14 plates. Demy 8vo, 10s. 6d. net.

GROWTH. By G. R. DE BEER, B.A., B.Sc. Demy 8vo, 7s. 6d. net.

PRINCIPLES OF BACTERIOLOGY AND IMMUNITY. By W. W. C. TOPLEY, M.A., M.D., F.R.S., and G. S. WILSON, M.D., B.S. 1360 pages, with 242 illustrations. Super royal. In two volumes. 50s. net per set.

AN INTRODUCTION TO THE STUDY OF THE PROTOZOA. With special reference to the Parasitic Forms. By the late E. A. MINCHIN, M.A., Ph.D., F.R.S. xii + 520 pages, 194 diagrams. Demy 8vo, 25s. net.

THE DEVELOPMENT OF BRITISH FORESTRY. By A. C. FORBES, F.H.A.S. xii + 274 pages, 70 illustrations. Demy 8vo, 10s. 6d. net.

PROCEEDINGS OF THE WORLD POPULATION CONFERENCE, 1927. Edited by MARGARET SANGER. 383 pages. Medium 8vo. 20s. net.

A HANDBOOK OF THE CONIFERÆ AND GINKGOACEÆ. By W. DALLIMORE and A. B. JACKSON. With 32 plates and 120 diagrams. Medium 8vo, cloth, 42s. net.

A BRITISH GARDEN FLORA. By Lt.-Col. J. W. C. KIRK, B.A., F.R.H.S., with a foreword by Dr. A. W. HILL, C.M.G., F.R.S. xii + 592 pages, with 223 diagrams. Medium 8vo, 42s. net.

ELEMENTARY BOTANY. An Introduction to the Study of Plant Life. By W. WATSON, D.Sc. viii + 368 pages, with 225 diagrams. Crown 8vo, 6s. 6d. net.

BN-9 80 3133-0

Date Due